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Government of the Philippine Islands
Bureau of Agriculture

Bulletin 33

CANE PRODUCTION AND SUGAR MANUFACTURE IN THE PHILIPPINE ISLANDS

BY

CLEVE W. HINES, M.S.
Sugar Technologist of the Bureau of Agriculture

MANILA
BUREAU OF PRINTING
1919

161900

PLATE I. Stool of sugar cane

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Bulletin No. 33

SUGAR PRODUCTION IN THE PHILIPPINE ISLANDS

INTRODUCTION

The production of sugar from sugar cane, sugar beets and the various sugar palms forms one of the most important industries of the world. While sugar is no longer classed as a luxury within the reach only of fortune's favorites but rather as a common food as well as a prime necessity, because of its wholesomeness, yet it needed the late war to bring home to the people at large its real value. That likewise taught the scientist how much sugar could be depended upon as a source of synthetical compounds in the chemist's laboratory; as a preservative, a base and a necessary constituent of medicine in the pharmacist's laboratory; and as a necessary factor in conducting various lines in the arts and trades. So, while the demand for this product has greatly increased each year during the past two or three decades, only to be met by a production of equal amount, it is evident that this demand will be greatly increased for some time to come. More sugar must be produced than ever before.

Here science steps in and by the application of knowledge gained through intensive research in the fields of chemistry, physics, geology, bacteriology, and botany makes it possible to obtain the utmost production of cane from the soil. Again, science fills an important rôle in the manufacture of sugar, pointing the way for maximum recovery of suitable grades at a minimum expense. The low yields resulting from the costly and wasteful processes followed in the past can no longer be tolerated. Today the world feels it can afford to waste nothing. And the Philippines are falling into line. While there are operating here numerous open kettle factories making the molasses type of muscovado sugar that at one time answered the world's requirements, still it is a question of only a short time until they will be considered relics of the past.

The sugar industry of the Philippine Islands dates back for hundreds of years. In fact sugar cane was one of the first cultivated plants observed here by the discoverers of the Islands. Although there are but fragmentary records on this subject of early date, it is evident that the industry was gradually growing in importance even before American occupation, when modern methods of sugar production were introduced. Since that time great improvements have been made, and today there is produced more than three hundred and fifty thousand tons of sugar annually, seventy-five thousand tons of which is centrifugal sugar.

It is estimated that there are enough suitable lands in the Philippine Islands to produce more than a million tons of sugar a year when modern cultural and manufacturing methods are more extensively employed. In former times there was a decline in the production, as crops were harvested from year to year until the lands were said to be "worn out" or "tired." A familiar example of lands of this type may be found in southern Luzon in the provinces near Manila, where a one-crop system was practiced for many generations. Although these lands are in poor condition, due to constant depletion of their plant food elements, yet they may be again brought into a good state of fertility and made to produce large crops when they are properly handled. This requires that a system of crop rotation be practiced in which various nitrogen-gathering crops, legumes, shall play an important part.

Since quantities of the necessary inorganic plant food elements potash and phosphorus have been removed in the harvesting of crops year after year during the time this soil has been bled, it may be found necessary to apply these elements in the form of special fertilizers. Calcium in quantities sufficient to build plant tissues is usually present even in the worst of these soils, but liberal applications every two or three years will greatly improve their physical condition; besides, calcium is important also in that it improves conditions for the leguminous plants rotated with cane. By crop rotation, soil feeding and giving attention to modern methods of agriculture in general, these lands may be brought again to a cultural condition in which they will produce large sugar crops.

Experiments conducted by the writer at some of the demonstration and experiment stations of the Bureau of Agriculture and on various plantations have shown that such a system of treating the so-called depleted, or better named mistreated, soils instead of being a heavy burden of expense to the planter has proved very profitable, netting most satisfactory returns on the extra outlay of expense, even the first year, in the shape of large crops harvested, while during the succeeding years the net returns, for all this extra outlay, have yet increased. And furthermore, great as is this immediate gain to the planter, it will be dwarfed by comparison with the benefit which will accrue to future generations because of the preservation of the fertility of the lands that will result from the establishment of a scientific system of permanent agriculture in the Islands.

HISTORY OF THE SUGAR INDUSTRY OF THE PHILIPPINES

As sugar cane has been grown by the inhabitants of the Philippine Islands since time immemorial, it is impossible to ascertain the derivation of the plant. But since this is a tropical plant of the *graminaceae* family, to which the cogon, talahib and tigbao common in the Philippines belong, it is not improbable that cultivated variants of this plant originated here. Of recent years a search has been made to determine whether there are promising variants of the sugar cane among the wild reed-like growths of the Islands, and a tall plant was discovered in the Province of Occidental Negros which greatly resembled the sugar cane. This plant was given the name of "tigbaw mestiza," as it was at first thought to be a natural hybrid between the tigbaw and sugar cane. A detailed description of the above cane will be given later.

The history of the industry proper is almost as difficult to trace as that of the cane itself. It has been observed, however, that there is a striking similarity in the methods and implements employed here to those on the mainland and nearby islands of China. The "pilon sugar" of the provinces of Rizal, Bulacan, and Pampanga, named from the earthen or pilon jar, and the massive granite rolls may be cited as evidence in favor of this theory. In Spanish times the small, animal-driven mills were no doubt the first used here; but in later years small steam engines were employed, and during the late eighties, or just prior to American's occupation, several small yet fairly good mills were installed which were equipped with vacuum pans. A rather unsuccessful attempt was then made to manufacture centrifugal sugar in the combined open kettle-vacuum pan factories. Such factories as those just mentioned existed at Bula, Ambos Camarines; Balayan, Batangas; Cabanatuan, Nueva Ecija; and Talisay, Negros Occidental, but during the period of unrest prior to American occupation, these plants were completely destroyed and only the muscovado industry remained. With the introduction of American capital and machinery, the

industry began to develop along modern lines and there are now operating modern plantation factories as follows:

Name of factory	Where located	When built	Capacity
			Tons cane per day.
Calamba Sugar Estate	Canlubang, Laguna	1913	1,800
San José Milling Company	San Jose, Mindoro	1910	1,000
San Carlos Milling Company	San Carlos, Negros Occidental	1914	800
North Negros Sugar Company	Manapla, Negros Occidental	1918	600
Bearing Central	Cabancalan, Negros Occidental	1914	500
Philippine Sugar Developement Company	Calamba, Laguna	1914	300
De La Rama Sugar Central	Bago, Negros Occidental	1913	300
Guanco Central	Hinigaran, Negros Occidental	1913	300
San Isidro Central	Cabancalan, Negros Occidental	1917	250
Carmen Central	Calatagan, Batangas	1914	200
Palma Central	Ilog, Negros Occidental	1916	200
San Antonio Central	La Carlota, Negros Occidental	1913	150
Dinalupihan Factory	Dinalupihan, Bataan	1913	125
Talisay Central	Talisay, Negros Occidental	1918	125
Canlaon Factory	Canlaon, Negros Occidental	1913	125
Muntinlupa Factory	Muntinlupa, Rizal	1912	100
Saint Louis Oriental Factory	Manaoag, Pangasinan	1912	90
Look Factory	Nasugbu, Batangas		

FACTORIES UNDER CONSTRUCTION OR PROJECTS DEFINITELY PLANNED FOR IMMEDIATE DEVELOPMENT

Hawaiian-Philippine Co	Silay, Negros Occidental		1,500
Pampanga Sugar Central	Floridablanca, Pampanga		1,500
Maao Sugar Central	Maao, Negros Occidental		1,500
Bais Sugar Central	Bais, Negros Oriental		1,000
La Carlota Sugar Central	La Carlota, Negros Occidental		1,000
Talisay-Silay Sugar Central	Talisay, Negros Occidental		1,000
Bacolod-Murcia Sugar Central	Bacolod, Negros Occidental		1,000
Isabela Sugar Central	Isabela, Negros Occidental		600

SMALL FACTORIES USING OPEN TRAIN EVAPORATORS AND VACUUM PANS

Pampanga Sugar Factory	Floridablanca, Pampanga	1916	100
Bernia Factory	Dinalupihan, Bataan	1918	90
Kennedy Factory	Isabela, Negros Occidental	1918	90
De la Viña Factory	Vallehermosa, Negros Oriental	1918	90
Tubigan Sugar Factory	Tubigan, Bohol	1917	90

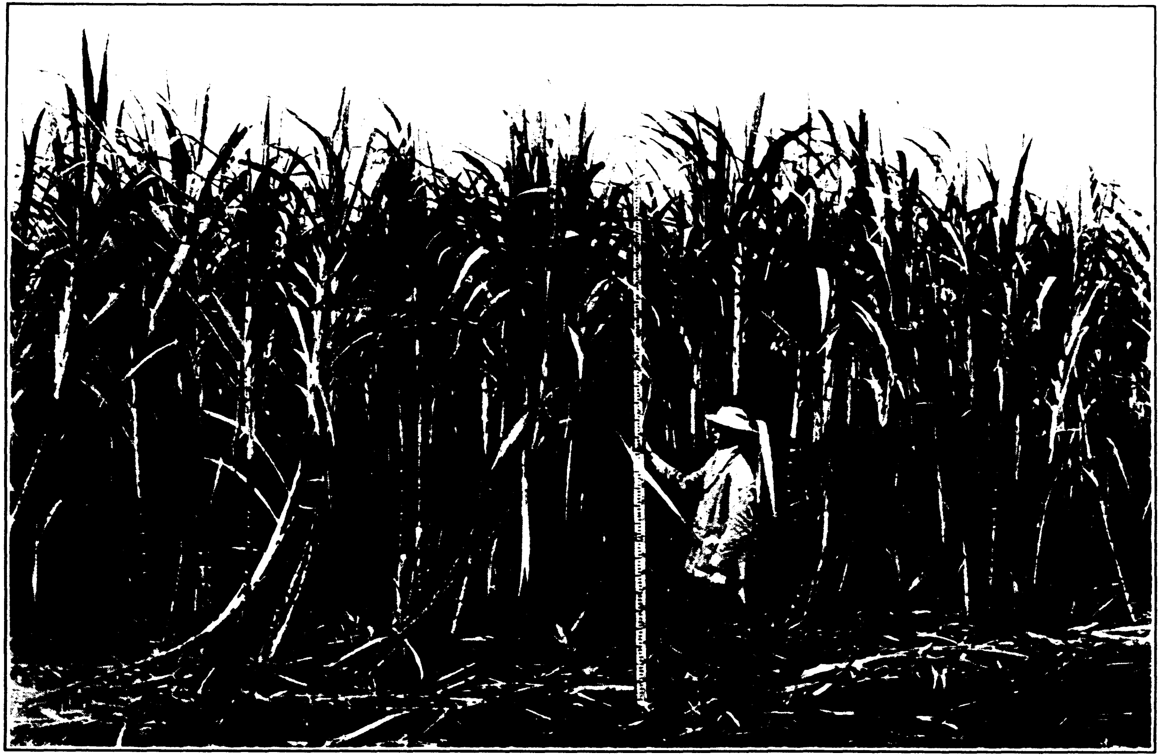


PLATE IV. Yellow Caledonia sugar cane growing at Alabang Stock Farm

SUGAR CANE VARIETIES

While it is possible that some of the cultivated varieties of sugar cane originated here either as seedling or bud variations, it is more than probable that others were introduced from the southern coast of China by travelers and adventurers. Among the varieties or variants that are presumed to be indigenous here may be mentioned the Tigbaw mestiza. In general appearance this cane very much resembles the large reed-like grasses common in uncultivated regions, since it throws out extremely large stools of tall, erect stalks with nodes and internodes much like those of the cultivated varieties of cane. The stalks of this plant are small in diameter and have long and deeply grooved internodes. The nodes are quite large and generally contain rudimentary rootlets. This cane is light purple in color, has very hard, woodlike tissues and when mature contains from 16 to 18 per cent of fiber and 7 to 8 per cent of sucrose. It arrows profusely at the age of one year and the flowers are invariably well supplied with fertile pollen.

There were four varieties of cane grown on the estate scale when America assumed control of the Islands; namely, Negros purple, Cebu purple, Pampanga purple, Luzon white; in addition to these Inalmon or Manila black cane was grown mainly for chewing, while there were a number of minor varieties of white, purple and striped cane grown on a small scale in isolated regions for home consumption.

The introduction of foreign varieties was begun by the Bureau of Agriculture in 1905, when a consignment of cane was received from the Hawaiian Sugar Planters' Association of Honolulu, consisting of White bamboo, Louisiana purple, Demerara No. 74, Singapore striped, and Tiboo mird. This attempt proved a failure due to fact that the cane had become very dry during transit.

The next essay was made in February 1910, when three cuttings of each of the following varieties were received: Hawaii Nos. 16, 20, 27, 69, 227, 309. Plate No. II is a view of these original cuttings. They were planted at the Alabang Experiment Station after they had been under observation for sufficient time to prove their value under conditions prevailing here and to determine their freedom from destructive insects and cane diseases. Plate No. III shows a field of these six varieties of cane growing at the Alabang Experiment Station in 1912.

During the time that the above varieties were under observation, Lahaina and Yellow Caledonia were introduced from the same place and given similar tests under local conditions. The latter proved to be a cane especially suited to the low, wet lands, while the former was better suited to the higher regions. Plate No. IV is a view of Yellow Caledonia cane taken at Alabang Experiment Station in 1913. In October of the year 1910, a small number of cuttings of the Demerara seedling varieties Nos. 74, 117 and 1135 were brought from the Hawaiian Sugar Planters' Experiment Station by Mr. H. J. Gallagher, then superintendent of the La Carlota Experiment Station. The first two varieties later died through poor germination resulting in weak plants; but the other, D 1135, survived and has proved an excellent variety for certain classes of light clay soils.

In the forepart of the year 1911, a small consignment of cane cuttings was received from Dr. W. G. Taggart, Director of the Sugar Experiment Station of Louisiana, through the Bureau of Insular Affairs, Washington, D. C. This consignment contained the following varieties: Louisiana striped, Louisiana purple, Demerara Nos. 74 and 95. The Louisiana striped variety has proved a valuable cane on many plantations, especially those containing a fairly heavy soil. The Louisiana purple has proven unsuitable and has given poor yields wherever experiments were conducted in the Islands. Both Hawaii No. 74 and No. 95 mature very early and due to their low yielding of cane under conditions here have proven unsuitable varieties.

In April of the year 1911, a 4-pound parcel of "Uba," or Japanese cane, was received from Chico, California. The original start of this cane came from Prof. S. N. Tracy of Biloxi, Miss. It was found to grow very tall and produce large stools much resembling various large grasses. This variety yielded well in cane but it always contained a low percentage of sucrose and a high percentage of glucose. It therefore proved a very good forage crop for plantation animals and where proper cultivation and irrigation were given three harvests could be gathered each year. Plate No. V shows a view of this cane growing at the Alabang Experiment Station in 1913.

During the latter part of the year 1912, Mr. H. B. Ross presented the Bureau of Agriculture with the following varieties of cane, which were brought from Australia: Imperial striped Cherbon, Mauritius malagache, Mauritius No. 1900, Malabar, Whitcalorum, New Guinea Nos. 24, 24A, 24B, Barbados No. 3141. The Whitcalorum failed to germinate, but so far the other varieties in this consignment have not proven especially suited to the Philippines.

During the latter part of the year 1912, Mr. George H. Fairchild, manager of the Mindoro Sugar Company, imported from Hawaii a number of cane varieties previously introduced by the Bureau of Agriculture, and in addition Hawaii No. 109 and Mexican striped. These two latter varieties have proven especially popular for certain classes of fairly heavy soils.

During the same year, 1912, Mr. Fairchild imported from Java seedling variety No. 247. This is a very hard cane and cracks badly during rapid growth, which accounts for the low purity usually observed in the juice.

In October, 1913, the Bureau of Agriculture imported from Saigon two varieties, Chinois and Big Tanna.

The former cane is very small in diameter and much like "Uba" cane except that the tissues are somewhat harder. The latter is a very large cane and contains a low percentage of sucrose, which makes it unsuitable as a source of sugar here.

In October of the year 1915, six varieties of cane were introduced from the Sugar Experiment Station at Pasoeroean, Java. This consignment consisted of the following varieties: Black Cheribon, P. O. J. Nos. 100, 213, 247, 826 and 979. Unfortunately the cane was delayed in transit and more than three months elapsed from the time of cutting until the points arrived for planting. Consequently they had deteriorated so badly that only two of the varieties, Black Cheribon and P. O. J. No. 213, survived.

In September of 1916, another consignment of cane was received from the same source. This contained the following varieties: P. O. J. 100, 213, 826, 979, 1499, 1507, 2542, E. K. 2, D152, B247 and Black Cheribon, Plate No. VI shows a view of this cane as it appeared upon its arrival at the Bureau. These points were all in excellent condition when received and were planted in quarantine at the Singalong Experiment Station in the variety plot containing all of the newly imported varieties.

On January 2, 1916, the following varieties were received from Formosa: Java Nos. 36, 105 and 143. These also were planted in the variety plot at the Singalong Experiment Station.

The next consignment of points was received on February 10, 1917, from the Cuban Experiment Station at Santiago, Cuba. These consisted of the following: Demerara Nos. 247, 604 and 625, Barbados Nos. 208, 306, 1753, 3412, 6204, 6308, and 6450, and Lucier-Blanco.

Results of Experiments with Native and Foreign Cane

Extensive experiments have been conducted with the native and foreign varieties of cane at the three experiment stations and at various demonstration stations of the Bureau of Agriculture. The average results of these tests covering a period of five years are as follows:

Variety	Average weight per stalk	Tons cane	Cane		Purity of juice
			Sucrose	Fiber	
	Kilos.	*Htare.*	*Pct.*	*Pct.*	
Negros Purple	1.25	65	13.1	10.3	86
Cebu Purple	1.20	64	14.5	10.2	88
Pampanga Purple	1.00	57	12.2	11.0	83
Luzon White	1.28	62	12.0	11.1	82
Inalmon (soft variety)	1.24	56	13.9	11.3	85
Hawaiian:					
No. 16	1.75	85	11.0	12.4	80
No. 20	1.78	-------	11.2	12.6	79
No. 27	1.78	86	11.4	12.5	79
No. 69	1.52	79	11.5	12.4	80
No. 109	1.77	87	12.5	12.4	83
No. 227	1.47	71	11.5	12.3	80
No. 309	1.90	93	11.1	12.7	79
Yellow Caledonia	1.94	94	10.9	13.0	76
Rose Bamboo	1.71	83	11.0	12.2	78
Louisiana Striped	1.80	89	12.7	12.1	83
Lahaina	1.75	81	12.4	12.4	82
Java No. 247	1.8	89	10.9	13.5	76
Big Tanna	1.96	90	10.8	13.0	76
N. G. No. 24	1.74	82	11.8	12.6	80

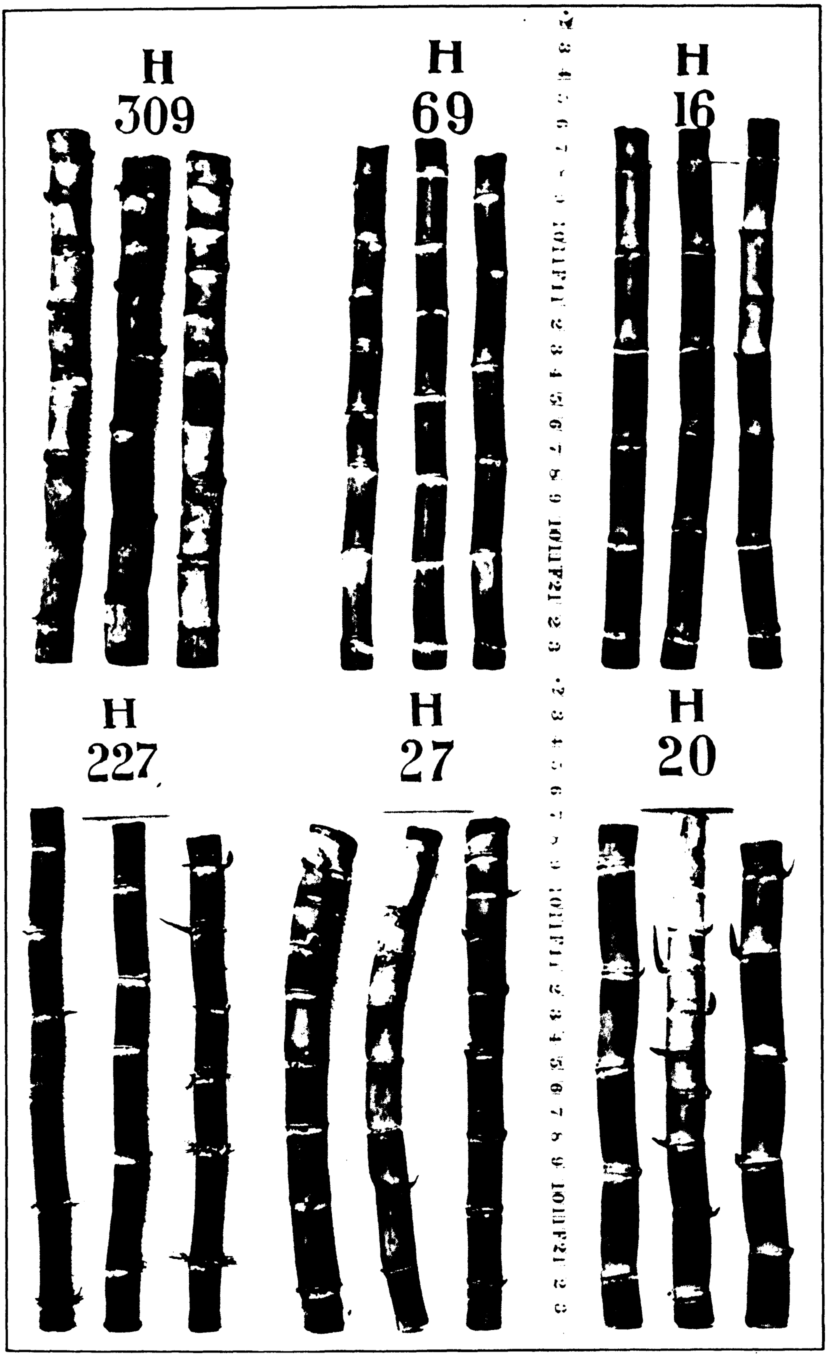


PLATE II. Original cuttings of Hawaiian seedlings varieties of sugar cane received by the Bureau of Agriculture from the Hawaiian Sugar Planters. Experiment Station in February, 1910

PLATE III. Six Hawaiian seedling varieties of sugar cane growing at Alabang Stock Farm, December, 1912

PLATE V. Uba (Japanese forage cane) at Alabang Stock Farm

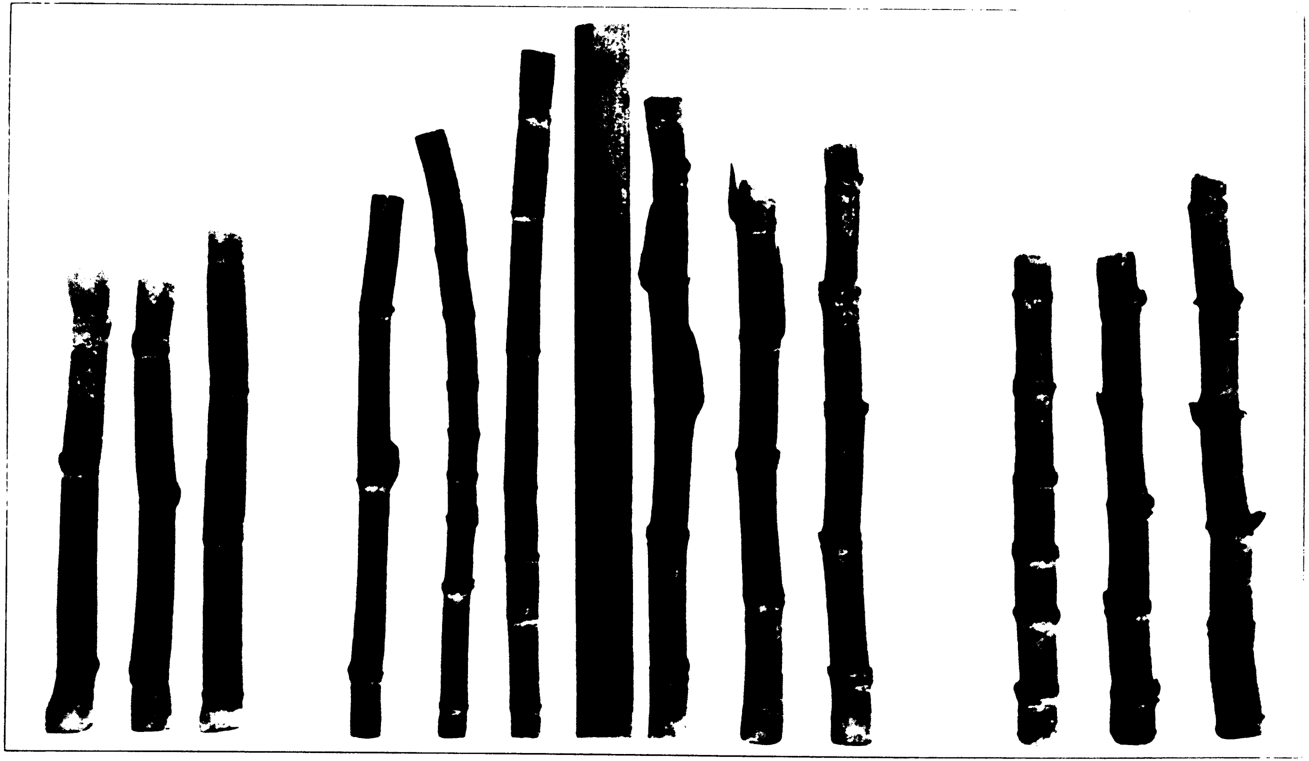


PLATE VI. View of Java cane points when received

SEEDLING CANE

The importance of increasing the yield of sugar was realized long before it was discovered that the seed of the sugar cane was quite often fertile and that distinct varieties might be produced therefrom. Previous to this discovery it was thought that the improvement of sugar cane could only be brought about by one of two methods: either through chemical selection of the varieties then cultivated, or through bud variations. Accordingly extensive experiments were conducted year after year on the cane then cultivated, with a view to selecting those stools or even individual stalks which gave the maximum yield of sucrose. This method of improving the varieties was obviously doomed to failure, since the new plantings were made only from scions or cuttings from the old plant and thus no material change could be made in characteristics of growth and composition of the new plant. It was observed, however, that different varieties of cane existed in the various countries and that even in the same country there might be found a number of different types of cane, such as the white, red, and striped.

The main stalk of the cane as well as the underground rhizome contains buds which provide a means of reproducing the plant without the employment of seed; and it has been observed that canes which differ greatly in external appearance may be thus produced. By selecting for planting those stalks with exaggerated characteristics, different so-called varieties are obtained which are more or less constant. This method of producing variations seldom causes any material difference in the characteristics of growth, except in appearance, however, and consequently no marked improvement in the quality of the cane results. The varieties or "variants" thus produced are known as "bud varieties."

Speaking from a botanical standpoint, many of the so-called varieties obtained by this methods as well as by means of seed are not in reality distinct varieties at all but merely casual variants. It is the general custom, however, to designate cane as a different variety when it shows a different color, slightly different growth, or any of the thousand and one other characteristics which distinguish the different kinds of cane.

Although great improvement had been made in the yield and quantity of various farm crops by careful cross breeding and seed selection, a noteworthy example may be mentioned in the case of sugar beet whereby both the yield and quality have been greatly improved; yet the growing of cane from seed and the improvement of the crop by the above means were considered an impossible task until comparatively recently, for it was believed that through constant planting from cuttings the cane had lost its power of producing fertile seeds. There was an earnest desire on the part of the planters, however, to produce larger and sweeter varieties of cane; and yet the method of accomplishing this end through the medium of cane seed was no more than hinted at until the harvest of 1887–1888, when the announcement was made that Messrs. Soltwedel, of Java, and Harrison and Bovell of Barbados, had succeeded in producing a number of cane plants from seed. This gave a new impetus to experimentation, for it was at once apparent that there was a ready means at hand of producing varied and distinct varieties by securing hybrid seed from the varieties which produced flowers.

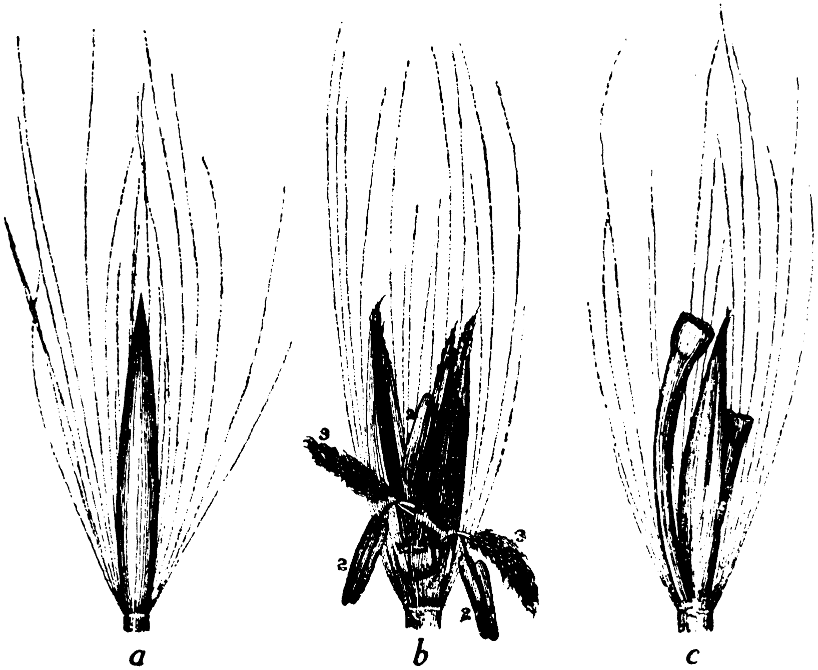


FIG. 1. Flower of sugar cane. (*a*) Just before opening. (*b*) Sectional view of the flower after opening. 1, ovary; 2, anthers; 3, styles. (*c*) Mature flower

Since the date of the above discovery, the production of new varieties has rapidly advanced, until today thousands of hectares are planted to varieties which originated from seed in the principal sugar-producing countries of the world; indeed there are few countries in which the native or original cane is grown exclusively today.

So much has this discovery done for the planter that it is today possible for the plant breeder to produce a variety exactly fitted to the conditions of a plantation, no matter whether a cane is desired for light or heavy soils; for a long growing season from twelve to eighteen months like that of many parts of the tropics, or for a short growing season of seven or eight months like that of the subtropics.

PHILIPPINE SEEDLING VARIETIES

So far as the writer has been able to learn, no attempt had been made to produce new varieties of cane from seed in the Philippine Islands previous to the year 1913. But a number of seedling varieties had been brought here from the various sugar-producing countries. These latter had proved very satisfactory in the countries in which they had originated, yet they had failed to produce the high purities so much desired by all muscovado sugar factories, although the yields of cane in most cases were much higher than those from the native varieties (See table p. 18). The varieties then grown most extensively on the different plantations consisted of the Negros purple, Luzon white, Cebu purple, Pampanga purple, and Inalmon or Manila black. While the majority of the native varieties possessed the favorable characteristic of producing a high percentage of sucrose and giving a juice with a high purity, yet on the other hand they offered the great disadvantage of producing low yields and also of having soft tissues, being thus more susceptible to the attacks of insects and rodents; and the soft tissues and low fiber content did not offer sufficient rigidity to enable them to resist storms.

After a careful study of the situation here, the writer became convinced that through the medium of new varieties, cane might be produced from seed which would offer a great improvement over both the native and imported varieties. It was also apparent that excellent material was available for the carrying out of this work, since the native cane gave a high percentage of sucrose and purity, while various introduced varieties were heavy yielders of cane although they contained a fairly low percentage of sucrose and gave a juice with a low coefficient of purity. He was at the same time impressed with the fact that should the previous practice be continued there was a very great danger of introducing into the Islands, along with the imported cane cuttings, various diseases of sugar cane which have proved so destructive to the industry in a number of the sugar-producing countries of the world; for although the cuttings may be carefully fumigated before planting, it is impossible to eradicate all of the various organic and fungus diseases without completely destroying the cuttings.

Preparations were accordingly made during the arrowing season of 1914 for preliminary work in the production of varieties especially suited to the conditions here, and at the same time to eliminate the danger of introducing destructive cane diseases. It was observed that certain varieties arrowed profusely, beginning sometime during the period from November 5 to 20, depending upon the particular season, and extending into the latter part of December or forepart of January. The native varieties, however, seldom arrowed at all and when they did produce flowers it was invariably at a time somewhat later than the foreign varieties.

In addition to a limited quantity of the native cane, all of the foreign varieties of this Bureau were grown at the Alabang Experiment Station where the work was begun.

EMASCULATING THE FLOWERS AND CARING FOR THE SEED

Since the arrows on the large cane are located from 4 to 5 meters above the ground, it was necesary to arrange a portable platform somewhere near the arrows upon which the work of emasculating the flowers could be performed in order to eliminate the bending of the stalks out of their natural position.

It was observed that the main branches in the central portion of the arrows produced the largest and most perfectly formed flowers, while those on the branches near the extremes were usually smaller. The interval of time between the first appearance of an arrow and its complete emergence from the leaf-sheath ranged from two to four days, while it required from two to three days after the flowers appeared for their organs to be sufficiently developed to begin to shed pollen. In consequence of this condition it was necessary to remove these flowers on the upper branches as soon as they appeared, in order to prevent the pollen from the older and more matured flowers above from falling upon the stigmas of the flowers used for the production of hybrid seed.

Rectangular frames covered with mosquito wire and, in some cases a very fine grade of muslin and in others with paraffine paper were used to protect the arrows from foreign pollen. These frames were each 20 centimeters square and 50 centimeters long and contained a small hole at the bottom through which was passed the stem of the arrow. The cages were supported on bamboo poles in order to leave the arrow as nearly as possible in its natural position. The boxes opened longitudinally, which permitted the free entrance of the arrow as well as observation of the flowers from time to time and the introduction of pollen. The arrows intended for treatment were inclosed in cages immediately after they began to appear beyond the leaf sheath and the upper branches were removed as fast as they were produced. A dissecting microscope as well as a high-power hand lens were used on the platform in the field in the carrying out of this work. All of the upper branches as well as the majority of the lower ones were removed, leaving from five to six in the central portion of the arrow. These were carefully examined each morning just after the dew had dried off, since it is at this time of the day that the flowers open. Just as soon as the flowers were sufficiently developed for the anthers to be detected the latter were clipped off with very small pointed scissors. Great care was necessarily taken in every case to see that none of the anthers had opened before their removal, in order to eliminate any possible chance of self-pollination. Since the stigma of the cane flower in common with that of many other flowers usually matures slightly before the complete development of the pollen in the same flower, it might seem that the task of producing hybrid seed would be extremely easy; and indeed it would if there was only one flower on each arrow. But on account of there being present on the same plant numerous flowers in all stages of development, there is in reality a very poor chance of producing hybrid seed in those varieties which produce an abundance of normal pollen unless artificial means are employed.

Pollen from the variety selected as the male parent was shaken over the emasculated flowers and an arrow containing numerous well-developed flowers was placed inside the cage, with its stem in a bottle of water to keep the flowers fresh; after which the arrow was again inclosed in the cloth-covered cage. This operation of pollenizing the flowers was performed once each day for at least one week after the emasculation of the flowers, care being exercised to effectively exclude foreign pollen during the operation. The cages were opened only when the air was very calm in order to prevent foreign pollen from being carried there by light gusts of wind. The flowers were then left from a week to ten days for the seed to mature, after which they were removed to the propagation sheds at the Singalong Experiment Station and planted in boxes containing rich, sandy soil. Both the hybrid seed and that which was collected from the untreated flowers germinated exceedingly well.

Half shade only was used over the plants during the early period of their growth but after they became large enough to possess sufficient vitality no further protection from the intense rays of the sun was provided. (See Plate IX–*a.*) When the plants reached a height of from 10 to 12 centimeters, they were removed from the boxes and planted in bamboo tubes as illustrated in Plate IX–*b.*

Since the first successful work on seedling varieties in the Philippines had started with this planting, each of the young plants, when transferred to the permanent plot for future observation and experimentation, was numbered consecutively, beginning with Philippine Islands (P. I.) No. 1.

It is during the first year that the process of elimination is started and those variants which prove to be below the standard are discarded. Among the characters aimed at for a variety suited to the conditions here are: (1) High available sucrose (i. e., a high percentage of sucrose, as well as a fair average purity of the juice); (2) yield of cane; (3) ratooning power of the cane; (4) fuel value of the cane (i. e., the fiber content); (5) resistance to extremes of drought and wet weather; (6) suitability to heavy or light soils; (7) resistance to attacks of insects and diseases; (8) condition of the tissue of the cane, whether soft or hard; (9) condition of the buds, their germination power; (10) habit of growth, whether straight or recumbent; (11) maturing period; (12) milling quality, etc.

So encouraging have been the results of the experiments made by the writer during the past five years that the Bureau has decided to give special attention to this work year after year in order that it may not be necessary to import cane varieties to meet the varied conditions here and thus run the risk of bringing in cane pests and diseases.

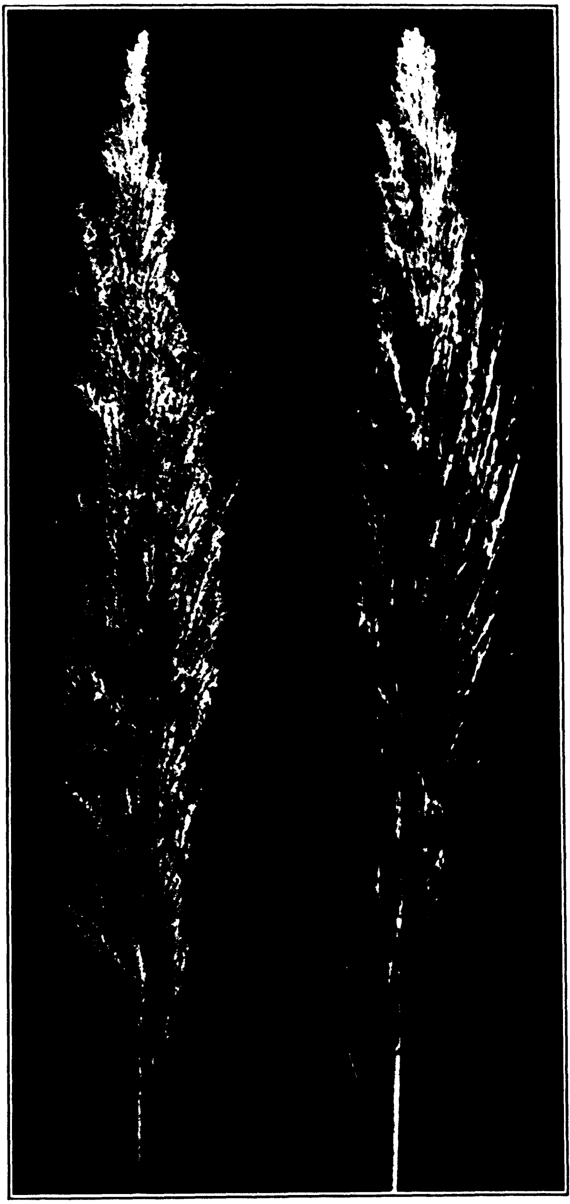
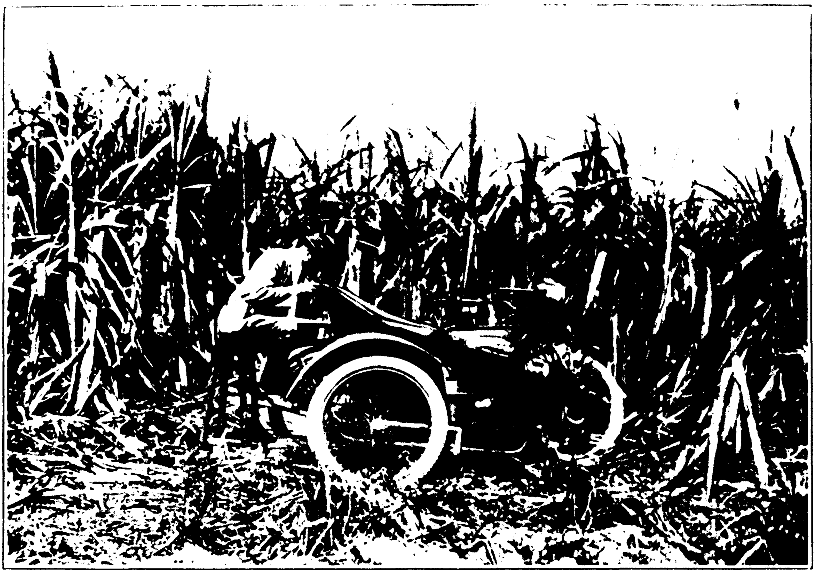
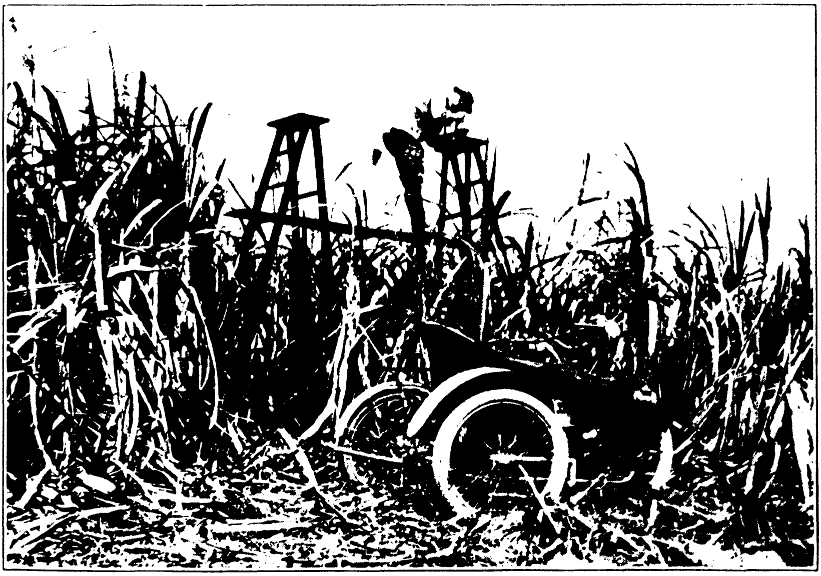


PLATE VII. Arrows of Louisiana striped sugar cane grown in the Philippines

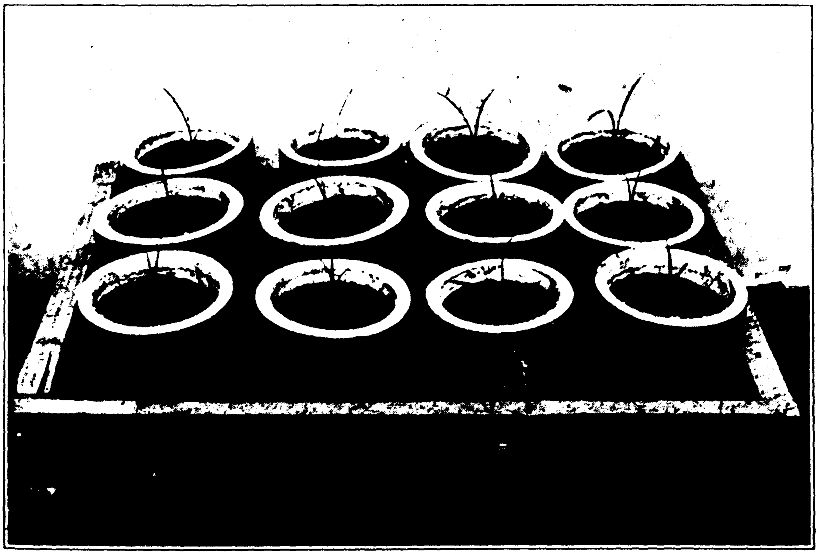


(*a*) Examining the flowers of sugar cane by the aid of a dissecting microscope



(*b*) Emasculating, or removing the anthers from the flowers of sugar cane

(*a*) Germination sheds in which half shade is used over the newly planted cane seed

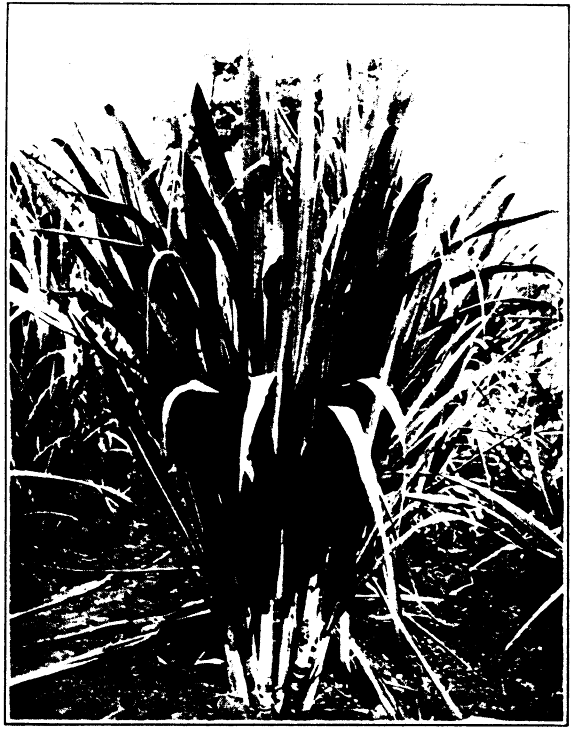


(*b*) Seedling cane planted in bamboo tubes

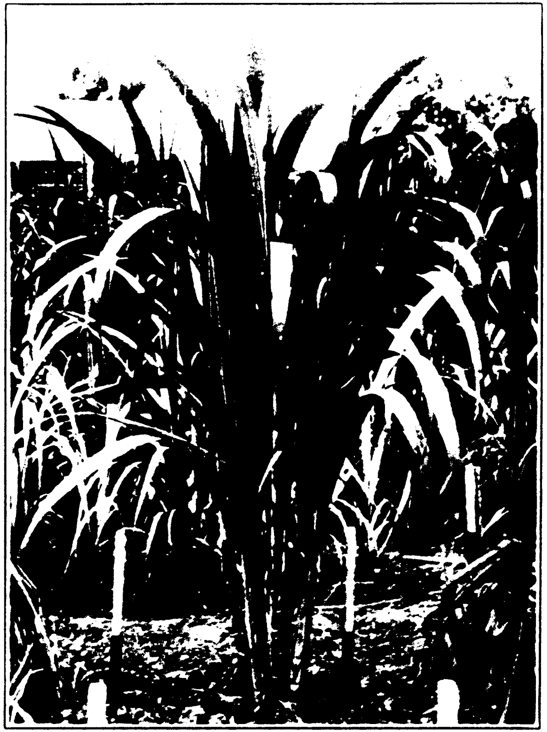
(*a*) The first seedling cane produced in the Philippines

(*b*) Seedling cane growing at the Lamao Experiment Station, July, 1918

PLATE XI.



(a) Philippine Islands seedling variety No. 2



(b) Philippine Islands seedling variety No. 24

ESSENTIALS IN THE PRODUCTION OF SUGAR CANE

Like the other members of the great *graminaceae* family to which sugar cane belongs, very little attention is required to promote its growth but in order to produce highly remunerative crops, as should be produced on sugar plantations, a number of factors must be given due consideration.

First. There must be employed suitable plant material to produce strong, vigorous plants for the future crop. This may consist either of cuttings or rhizomes from the previous harvest. The seed of the sugar cane is of great importance in producing new varieties of cane but it is not used in extending the planting.

Second. There must be provided a suitable home for the plant and this includes a soil wherein there exist proper physical and chemical conditions.

Third. There must be present in the soil, in suitable form, all of the plant-food elements necessary to build the tissues of this particular plant.

Fourth. There must be present an abundance of moisture, light, heat, and air.

Fifth. There must not be present in the soil in appreciable amounts the various organic and inorganic plant toxins or poisons.

Sixth. There must not be present to any extent the various biological enemies destructive to this plant.

The majority of these factors lie within the control of the planter and if proper attention is paid them much larger crops will result than those ordinarily harvested from the cane lands of the Philippine Islands, while at the same time conditions may be maintained for the production of heavy crops for posterity. But if they are neglected, there will be a gradual reduction in the yield, year after year, until very small crops are harvested and the land is classed as exhausted, as are many of the older cane lands here. It must be admitted, though, that the term "exhausted soil" is a misnomer as applied in a great many cases to the soils used in the production of sugar cane; for approximately 99.5 per cent of the material composing this crop is derived from the inexhaustible supply of air and water and only about .5 per cent is obtained from the soil and the majority of this material may be recovered in the by-products and used over and over again.

SOIL CONSTITUENTS

The term soil refers to the very complex structure composing the surface of the earth. Soils vary greatly in depth as well as in composition on the various plantations. It is difficult if not impossible to find identical soil specimens in the different parts of the same plantation, however closely they may resemble each other in their external appearance. A knowledge of the evolution and a complete history of the various soils on the plantation supplies the up-to-date sugar planter with information that is not only interesting but also important since it leads to the proper handling of each particular type of soil in order to produce maximum crops.

The formation of soils from the decomposition of rocks and organic matter is not a task that was completed in times gone by. The agencies which brought about these conditions from the time the earth's surface consisted of rock formations are bringing about similar changes today. These changes go on at a more rapid rate however when the intelligence of man is employed in devising methods of handling soils which cause more rapid disintegration and the consequent decomposition of the rock particles into a form available for plant nutrition. It may be said that no soils are "made" but that they are all in the making, and the rapidity with which this transformation takes place on cultivated fields depends largely upon the treatment they receive.

Soils consist of a mixture of the rocks and rock particles constituting the greater portion of the mineral matter and the remains of plant and animal tissues that make up the organic matter. In addition there are always present various gases and water.

The rock particles are for the most part inert material as far as their direct aid to plants in providing them with plan food material is concerned. These particles, however, perform a very important function in maintaining a suitable dwelling place for the root system of the cane, as will be observed later.

Soils are roughly divided into surface soils and subsoils. The former make up the upper stratum, which contains more or less organic matter. The limit of the surface soil may usually be determined by the darker color and difference in the appearance of the formation. Even in the surface soil the rock particles are never entirely decomposed; for in such a condition the plant food material would be leached away and lost before it could be used by plants, while, at the same time, the physical or mechanical condition would be greatly impaired.

The shallow stratum of earth lying immediately beneath the soil is designated as the subsoil. This contains but a limited amount of organic matter, derived mainly from the roots of plants and from the excrement and bodies of burrowing insects. The rock particles in the subsoil do not present the advanced stage of decomposition found in the upper stratum or surface-soils, due to the fact that they are acted upon to a lesser degree by the air, sunlight and water. Below this stratum still less decomposition takes place and the soil here quite often presents the form of the original rock. As the upper surface is cultivated, year after year, and heavy crops are removed with each harvest, the surface gradually wears away until, if deeper plowing were not resorted to yearly or, rather, if a small amount of this crude material from the sub-soil were not yearly mixed in, the cultivated area would in time become very shallow. It is therefore customary to plow just a little deeper each year than the previous year and gradually break up this lower stratum so that it will be reduced to fertile soil. In this connection it may be remarked that the implement known as a subsoiler serves an important purpose on sugar plantations, since it causes the lower stratum to be broken up without the addition of such a large amount of this crude material to the surface soil as would result from the use of an ordinary plow. This material would impair the fertility of the soil until the soil-forming agencies could convert it into a suitable form. This subject will be discussed further along, with soil preparation and cultivation.

There are three classes of soils with which the various sugar planters of this age have to deal; namely, virgin soils; those which have produced crops year after year and, through proper treatment, have been maintained in fertility; and the so-called "worn out" soils, or those which have been improperly handled.

In early days, when there was an abundance of virgin land available, it was considered an easy task to clear this land and plant whatever crop was desired, year after year, until the land was in such an unsuitable condition for the growth of cultural plants that it no longer produced satisfactory crops. The planter was then ready to move on and select another suitable tract of land, there to repeat his same methods. The demand for farm products was not so pressing, too, which was another reason why such methods could very well be tolerated. With the increasing population and the establishment of better standards of living throughout the world, economic conditions will not permit such waste to take place. The farmer nowadays has either to suffer the results of such ill-treatment given the soil or devise means whereby the harvesting of large crops may go on indefinitely. Such conditions are coming about in the production of sugar, as the full importance of this product both as food and in the arts is properly realized. This will eventually result in the survival of the fittest among sugar planters, and those who are not able to do their all in the world's great economic problem will be relegated to other tasks and replaced by the efficient.

When it is considered that various soils in China have been cultivated constantly for thousands of years and produce larger crops today than they did when first cultivated, it must be admitted that the treatment those soils received had much to do with increasing or even maintaining their fertility. If such results are attained only by studying nature's way in a rudimentary fashion it is easy to see what can be expected when planters realize the value of a constant application of the science of agriculture in the production of crops.

The practice so extensively followed on many sugar plantations of letting the land lie fallow, after the production of a number of crops of cane, if the yield begins to decrease, no doubt has some virtue in it, provided that conditions are favorable for the operations of the nitrifying bacteria; but it is not absolutely necessary that it should be resorted to when modern ingenuity would have the land producing a remunerative crop while at the same time increasing in fertility. The practise of rotating crops, the more especially when one of them is a legume, not only tends to permit the toxins from the previous crop to be oxidized and destroyed but also permits the storing up of nitrogen; and if the crop is turned under or used for pasture a valuable supply of organic matter is added as well. In the light of modern investigations into soil fertility it is evident that something more than a favorable physical composition and a fair content of the necessary plant food elements are required to make a soil productive. It has been demonstrated that many of the so-called worn-out or exhausted lands are in reality better prepared to produce large crops, so far as their physical condition and the supply of available plant-food material are concerned, than some of the soils classed as being fertile. Many sugar planters believe that there must be present in the soil a very large supply of the necessary plant-food elements and that a chemical analysis of their soil is the only guide that will be required to lead them to the road of success in the production of sugar. This is an erroneous idea, as planters have often learned to their sorrow. It will not be disputed that a soil analysis is a valuable guide to the agricultural expert to aid him in determining the treatment to be given the soil, but it is a dangerous guide in the hands of the ordinary planter when he relies entirely upon its results for his store of information on the soil, as is quite often the case. Even if the analysis showed the exact amounts of the various elements in a form available to the plants, it would yet fall short of giving the necessary information leading to the production of large crops, though it would be a valuable guide in this respect.

Roughly speaking, each ton of sugar removes from the soil 1.5 kilograms of potash, 1 kilogram of phosphoric acid, 0.8 kilogram of nitrogen and 1 kilogram of lime. Where proper cultural conditions obtain, the root systems of the various rows will overlap and consequently the entire area of the field will be drawn upon to supply the plant with these elements. Assuming that the ordinary depth to which the soil is plowed will be 20 centimeters and that the root system of the cane will not extend beyond that depth in search of food (which is not in reality a fair assumption), a hectare of land the chemical analysis of which indicates the presence of 0.40 per cent potash, 0.12 per cent phosphoric acid and 0.80 per cent lime and 0.18 per cent nitrogen, will contain approximately 10,627 kilos of potash, 3,188 kilos of phosphoric acid, 4,783 kilos of nitrogen and 21,255 kilos of lime.

There would be present in this shallow depth of soil only enough nitrogen to produce 5,980 tons of cane, enough potash to produce 7,085 tons and enough phosphoric acid to produce 3,188. The above calculations are based upon the total exhaustion of the soil included in the shallow stratum of 20 centimeters and do not allow for the plant-food material removed from beyond that depth—that which would be returned with the ash from the bagasse and other sugar-house refuse—and the nitrogen from the air deposited in the soil by legumes, when a proper system of crop rotation is practiced for maintaining soil fertility. However, while the above figures are interesting as indicating the possible limitations of the plant-food material which is returned, yet in the light of scientific agricultural methods they do not indicate much to the up-to-date sugar planter.

High-grade sugar consists of almost pure sucrose, which is a carbohydrate with the chemical formula $C_{12}\ H_{22}\ O_{11}$, or carbon twelve parts, hydrogen twenty-two parts and oxygen eleven parts. The entire mineral constituents of the plant, together with the nitrogen, are discarded in the production of high-grade sugar, so these are found only in the by-products of manufacture. Where the by-products are applied to the soil, practically the entire amount of plant food elements removed with the previous crop are returned to the soil. Fortunately the majority of them are in a form directly available to the plants. During the combustion of the bagasse at the factory, the nitrogen escapes and is lost; but a new supply is readily obtained by growing legumes. Thus by a system of plant rotation the supply of this element instead of being depleted may be increased.

The presence of soil toxins or plant poisons exerts a remarkably detrimental effect upon growth. All plants give off material which is more or less toxic to that particular plant and to many other classes of plants as well. A noteworthy example of this nature may be found in the various sugar districts of the Philippines, where the large reed-like plants *Saccharum spontaneum* (known as "tigbaw" and thought to be a remote ancestor of the sugar cane), grows in abundance on the uncultivated lands. It is utterly impossible to grow a good crop of sugar cane on such lands unless they have been given special treatment previously. This usually consists of plowing the land and throughly incorporating in the soil a large supply of lime either in the carbonate oxide or hydroxide form and in keeping the soil well aërated by plowing and disking from time to time. This treatment entails the loss of the land for at least a year and even then the first few harvests of sugar are not so good as the succeeding ones unless corn or some other crop is previously planted.

PHYSICAL CONDITION OF SOILS

The various chemical elements of soils are present in the form of both mineral and organic compounds. The proportion of each of these two constituents present as well as the condition in which they exist exert as great an influence upon the productivity of a soil as do the chemical compounds themselves.

Sugar cane does best on soils not only properly supplied with the necessary plant-food elements but also where suitable physical or mechanical conditions exist. Under such conditions the roots are able to reach out a very great distance to secure plant food and at the same time the soil waters are better able to bear dissolved plant-food material to the rootlets as well as to transfer appropriate chemical compounds which serve to neutralize detrimental plant toxins. It is the favorable physical conditions within the soil that are largely responsible for the heavy yields of cane on well cultivated plantations.

Unlike many other plants of the *graminaceae*, the sugar cane sends up numerous stalks, due to the development of its rhizomes or underground stems in the root system. Where these rhizomes are improperly fed or where unfavorable growing conditions exist, the number of stalks that are produced to each stool of cane is curtailed and a smaller growth also results. In the production of a successful crop of sugar cane there should be not less than 100,000 stalks per hectare. If suitable conditions obtain within the soil for the growth of the cane so that it may properly develop, each stalk should weigh not less than one kilo.

The average number of stalks produced per hectare on various plantations of the Philippines which are in poor physical conditions ranges between 40,000 and 60,000 instead of 100,000 stalks as on well cultivated plantations. The production of such a small number of stalks is due largely to the fact that the eyes or buds of the rhizomes are so securely inclosed by the soil particles which are tightly cemented around them that it is impossible for the buds to develop.

It is no doubt true that if all of the buds of the rhizomes developed the stalks would be so crowded together that they could not grow properly, but this condition has never caused planters any great alarm, for nature has made a very wise provision against such a happening. It is, therefore, no excuse for the planter to neglect the physical condition of his soil.

TEXTURE

The texture of a soil refers to the size and the proportion of each class of soil particles present. This factor governs largely subdrainage as well as the moisture retaining capacity of soils. The texture of a soil is determined in the mechanical analysis by passing the specimen over screens of certain specified meshes. The various types are roughly classed according to the United States Bureau of Soils as follows:

Clay	0.005
Silt	0.050–0.005 m. m.
Very fine sand	0.100–0.050 m. m.
Fine sand	0.250–0.100 m. m.
Medium sand	0.500–0.250 m. m.
Coarse sand	1.000–0.500 m. m.
Fine gravel	2.000–1.000 m. m.

Particles larger than 2 millimeters in size are classed as gravel and stone.

Soils never contain particles all of the same size, but on the contrary they are composed of a mixture of all of the above-named particles together with organic matter, and the proportion of the various constituents present determines the class of soil that is formed. A clay soil is not one where all the particles are less than 0.005 millimeter in size, but one in which there is a preponderance of the above class of particles although there may be present any or all of the other constituents.

A soil which is composed of large particles is said to have a coarse texture. Such a soil is of poor moisture-holding quality; it also permits the plant-food elements present in a soluble form to leach away and thus it is very likely to be somewhat deficient in available plant-food material. This results since gravity water readily passes among the soil particles and drains away, carrying along dissolved plant-food material. Such soils do not convey suitable quantities of capillary water to the surface and in addition they hold but a limited amount of hydroscopic moisture, as their total surface area is small. On the other hand a coarse textured soil offers better opportunities for aëration or soil ventilation, whereby a supply of air is retained in the pores for the oxidation of the soil particles and the plant toxins, as well as to supply oxygen to the roots of the plants.

Conversely, the soils with a fine texture, like many of those found in the Isabela district, offer resistance to drainage and aëration; but at the same time they do not permit the water to drain away so readily as to carry an abnormal amount of soluble plant-food material with it; consequently such soils are usually rich in soluble plant-food material.

Each of the two classes of soils, with reference to its physical condition, has certain points in its favor as well as certain other distinctly unfavorable qualities. It will be observed from the mechanical analysis of productive cane soils of the world that a medium between the two extremes, other conditions being equal, gives the best results.

The gardener often finds it advantageous to alter the texture of his soil by making it lighter or heavier, as the case may be. This he accomplishes by applying certain materials to give the desired mechanical texture. Obviously this could not be done on sugar plantations where there are hundreds or even thousands of hectares under cultivation; so other means must be devised for handling the situation. It has been the writer's experience that distinct methods of handling each particular class of soil must be employed if maximum results are to be obtained. Some soils are greatly improved both chemically and mechanically by applications of lime, while others might possibly be harmed by such treatment. Applications of organic material will undoubtedly improve the majority of soils, while they would not improve and might even be detrimental to certain classes of peaty and muck soils.

Some soils will puddle badly when plowed wet, and bake or become very hard after drying. They are in poor physical condition for some time after being plowed because the particles have become cemented together forming large and firm lumps. Other soils lose their moisture readily unless a mulch of fine earth is maintained over the surface. The former should be handled when there is not an excess of moisture present, while the latter should be prepared while there is yet an abundance of moisture; and in the latter case every possible advantage should be taken to mulch the surface and thus to guard against the escape of the moisture which will be of material importance during periods of drought. The various parts of the plantation contain soils differing materially from each other and it is the duty of the planter to apply methods best suited for the handling of each particular class. This he can do without any great difficulty and thus offset their unfavorable texture.

SOIL ANALYSIS

A complete analysis of a soil forms a valuable means of determining the soil requirements for sugar cane as well as determining proper methods of handling the soil. Such an analysis implies a chemical, physical and bacteriological classification of its constituents.

The chemical analysis determines the content of the necessary plant-food elements in the soil but it does not always indicate the amount of this material that is directly available to the plants; so the analytical report is quite often misleading to the ordinary farmer. It shows the limitation of plant food in that particular soil, however, and may indicate these elements to be present in great abundance; yet in actual field practice it is often found that the soil absolutely fails to produce the expected yields. This may be due to various causes, among which is the fact that these elements are present in such combinations as to be unavailable to the plants. As an example of this type may be mentioned the various forms in which phosphorus exists, including phosphoric acid, which is extremely soluble and available to all plants; mono-calcium phosphate, which is also quite soluble and available to plants; di-calcium phosphate, which is less soluble and in consequence less available; and the tri- and tetra-calcium phosphate, which are practically insoluble.

It is obvious that a soil analysis is of more especial value to the agricultural expert who has made a thorough study of various soils; and due to his store of information on this subject, by deduction, he is better able to arrive at definite conclusion through the application thereto of the analytical data on that particular soil.

If a soil survey has been made of the entire vicinity, showing both the chemical and physical condition of the various soils, his work is simplified and his deductions more accurate. But he is not able to state definitely from the chemical analysis alone of that particular soil just what would be the best method of handling it.

In order that the analysis may be of any value at all, the samples to be analyzed must represent an average of the soil existing throughout a given area.

The following instructions for the taking of soil samples in the Philippine Islands have been issued by the Bureau of Science:

> Make a general inspection of the region, and select a representative field; i. e., one free from any modifications due to local conditions such as erosion, washing, etc. Inside the tract to be sampled, select five or six representative places some distance from houses, fences, roads or trees and, in cultivated fields, midway between two plants; remove the surface accumulations of grass, leaves or litter, and take sample with soil tube or auger. A spade may be used if precautions are taken to dig a hole one wall of which is smooth and perpendicular, to the proper depth and to take the sample of soil from the side of the hole in a slice about 8 or 10 centimeters thick. Avoid mixing the layers of different depths. The sampling should be done preferably when the soil is reasonably dry, after the crop has been harvested and before fertilization.
>
> *Surface-soil*—Sample each of the five or six spots chosen to a depth of 15 centimeters (6 inches) or to the change between the surface soil and subsoil, in case such change occurs between the depth of 15 and 30 centimeters, and place these together as representing the *surface soil. In no case is the sample to be taken to a greater depth than 30 centimeters (12 inches)*.
>
> If the surface soil extends to a greater depth than 30 centimeters, take a separate sample below the depth of 30 centimeters to a change between the surface soil and the subsoil or to a depth of a meter if no change occurs. This sample of the subsoil should be obtained in other respects precisely like that of the surface soil.
>
> *Subsoil.*—The depth to which the sample of subsoil should be taken will depend on circumstances. It is always necessary to know what constitutes the foundation of a soil to the depth of one meter at least; but in ordinary cases 25 or 30 centimeters will be sufficient for examination in the laboratory and should be taken in precisely the same manner as the surface soil.
>
> If the surface soil extends to a considerable depth below 30 centimeters, the sample of subsoil may be taken with less exactness, perhaps at some ditch or other accessible point, and its physical characteristics noted; i. e., whether a clay, rock, sand, etc. Combine the borings of a given depth. Empty these large composite samples in turn upon canvas, oilcloth, blanket, large heavy paper or floor, so as to protect the sample as much as possible. Break all lumps and mix thoroughly. Divide the sample by "quartering" and discard the two diagonally opposite quarters; mix the remainder and again quarter, repeat the process until only about one and one-half to two kilograms are left, and place in cans or in tight canvas or muslin sacks for the laboratory.

The physical or mechanical analysis of a soil forms practically as valuable a guide to the soil expert as does the chemical analysis, since this indicates, to a large extent, the susceptibility of the soil to subdrainage, subirrigation, baking or becoming hard, as well as the decomposition of soil particles and consequent liberation of plant-food elements. The more finely divided the rock particles are the greater will be the amount of hydroscopic moisture they will hold and the more readily will decomposition take place.

The bacteriological analysis indicates the content of microorganisms in the soil. This subject is being given greater attention every day by scientists, since it is found that various soil bacteria and moulds serve a very important purpose in the liberation of plant-food material as well as fixing in the soils nitrogen from the air.

While a soil analysis is a valuable adjunct in determining the fertility of a soil, yet this should not be considered a final proof of the fertility. It is always a good practice to maintain on the plantation one or more plots of land of uniform character where the various fertilizing elements themselves may be applied singly and in combination.

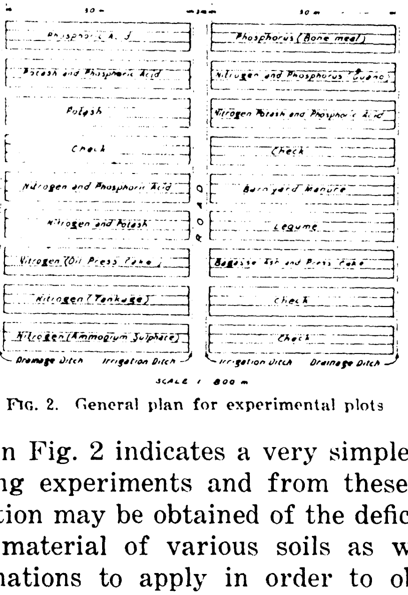


FIG. 2. General plan for experimental plots

The diagram in Fig. 2 indicates a very simple scheme of conducting fertilizing experiments and from these tests the most reliable information may be obtained of the deficiencies in available plant-food material of various soils as well as the best fertilizer combinations to apply in order to obtain maximum yields.

COMPOSITION OF SUGAR SOILS

Chemical analysis of soils from the various sugar lands of the world, and indeed from sugar soils in the same country, indicate that there is a wide variance in their chemical constituents. The following is a list of the analyses from various sugar lands.

Sugar soil of Louisiana (from Doctor Stubbs' "Cultivation of Sugar Cane")

	Per cent.
Lime	0.500
Potash	.400
Phosphoric acid	.100
Nitrogen	.100

Hawaiian Islands (from Noel Deerr's "Cane Sugar")

	Per cent.
Lime	0.631
Potash	.366
Phosphoric acid	.268
Nitrogen	.290

Sugar lands of Java (analyzed by Kramers)

	Per cent.
Lime	1.530
Potash	.079
Phosphoric acid	.090
Nitrogen	.061

Sugar lands of Occidental Negros, Philippine Islands

	Per cent.
Lime	1.660
Potash	.200
Phosphoric acid	.150
Nitrogen	.140

MINERAL MATTER OF CANE SOILS

The greater percentage of the substances from which soils are formed consists of mineral matter. This is derived entirely from the rocks and may consist either of the original rock particles or their remains after decomposition has taken place. The character of the rock formation from which the soil particles were derived determines, to a very great extent, the class of soil that is formed; the degree to which these particles are decomposed largely determines the fertility of the soil. The rocks found in the immediate vicinity are not always responsible, however, for the character of the soil that is formed, since these rocks particles are quite often brought from great distances by such agencies as the wind, water, and volcanoes. The transported soils thus produced are found on many plantations in the various sugar districts of the Archipelago.

It is quite often observed that the rich alluvial soils like those of the Isabela district of Occidental Negros largely result from the transporting to the valleys of great supplies of humus-forming material from the higher surrounding country. The average constituents of plant food material in the soils of this particular valley show it to contain approximately 1.46 per cent of nitrogen, 1.86 per cent of phosphoric acid, 0.13 per cent of potassium and 1.50 per cent of lime. The rich soils at the foot of Mount Canlaon in Occidental Negros, Mount Isarog in Ambos Camarines and Mount Mayon of Albay were the result of deposits of volcanoes. These regions have always been particularly rich in potash, and the volcano deposits have provided material for such a favorable mechanical condition in the soils that a dense growth of vegetation has grown up, the decay of which has caused a large supply of humus to be formed.

The original rocks from which the soil was derived are broken down by such agencies as the flow of water, changes in temperature, wind, volcanoes, plants, and animals; and the particles formed thereby are readily acted upon by the various chemical elements and compounds, thus causing the plant-food material therein contained to be changed into a form available to plants. While these chemical changes would take place to some extent even though the rocks were not broken into smaller particles, yet the change would go on more slowly, because a smaller surface area would be available for the chemical action.

The corroding or rusting of iron, the softening of brick and stone used as building material and the crumbling of rock surfaces are all familiar examples of this chemical change. The air, which is composed of various gases, assisted by water and sunlight, performs an important function in the decomposition of soils; and this is one of the points favoring cultural methods which keep the soil in a well aërated condition. Another thing of importance in bringing about this change is the soil water, which is quite often laden with the weaker acids such as humic acids. These tend to decompose the various rocks, forming new compounds which are usually soft and readily dissolved. A third factor of importance is the presence in the soil or carried about by the soil water of sodium chloride (common salt) calcium sulphate (gypsum) and numerous other chemical compounds. When these substances come in contact with certain classes of rock particles, there results an interchanging of the elements with the liberation of soluble plant-food material. The increased crop yields resulting from applications of such material have given rise to the mistaken belief among planters that they constitute fertilizing material.

Several planters have applied gypsum, or land plaster, indiscriminately to their soils with the result that the crop yields were materially increased the first year or two but the later yields were smaller than those experienced before its application.

While it is highly desirable to have a sufficient supply of available plant-food material present in the soil for the immediate needs of the crop, there is danger of an unnecessary loss through leaching if too much of this material is liberated at a time. For this reason it is important that such chemical compounds be applied to soils with extreme care, if indeed they are applied at all. It should be borne in mind that only the required amount of any such chemical to liberate a limited supply of the plant food should be employed at one time.

There are soils which analyses show to contain an abundance of the necessary plant-food elements but in practice they fail to produce well. In many such cases it has been found that one or more of the necessary plant-food elements is unavailable or locked up, so to speak, and hence it was of no service to the plants. It is highly desirable that suitable conditions in the soil be maintained, which will cause the rock particles to be decomposed and permit this plant-food material to be gradually liberated for the use of plants. To accomplish this the farmer should see that his land is kept in a well aërated condition. He should make liberal applications of lime, especially if the soil is acid, lacking in this element, or heavy. The lime in some cases may interchange its calcium for plant-food elements contained in the rocks and thus cause their liberation in a soluble form for the use of plants. He should have a large supply of organic matter well incorporated in the soil. Should these as well as other methods which will be mentioned later fail in bringing about the desired result, applications may be made consisting of the proper amount of appropriate chemical compounds to assist in decomposing the rocks and liberating the plant-food elements.

Among the various elements required in building up the tissues of plants may be mentioned phosphorus, potassium, nitrogen, calcium, oxygen, hydrogen, carbon, sulphur, silicon, magnesium, sodium, chlorine, and iron.

The majority of these elements are present in abundance in all soils. The first four elements are sometimes referred to as the necessary plant-food elements, since these are present in relatively large quantities in plants. As they are quite readily lost from the soils by leaching and other means, they are sometimes applied to the soil in the form of fertilizers.

The oxygen, hydrogen, and carbon are present in great abundance in the air and soil waters, while nitrogen is present in unlimited quatities in the air. Nitrogen is unavailable, however, to such plants as sugar cane, while in the pure state, as in the air; this element must first be deposited in the soil by one of the leguminous plants now used extensively on the plantations conducted along modern lines, or by means of bacteria which thrive without a host plant.

In case of sugar cane the principal elements contained are derived mainly from the air and water. Only about one-half of one per cent consists of mineral matter but without this constituent it would be utterly impossible to produce a crop of cane.

It is evident that nature has made a very wise provision for the feeding of plants and has endowed them with power to obtain the necessary plant food even when there is but an infinitesimal amount of each particular element present. It is absolutely essential, however, that these elements exist in a form available for their assimilation. A noteworthy example of this nature is found in the seaweed (kelp or *mammaria*) which extracts great quantities of iodine from the water of the ocean, though delicate chemical tests reveal the presence of but a negligible quantity in the sea water.

In parts of the Philippines there are rich lands that are covered with tigbaw and cogon. These soils fail to produce large crops mainly because of improper assimilation of the plant food contained, by the cane, due to the effect of toxic material. Such soils require proper treatment to neutralize the toxins from the previous growth and restore suitable conditions for the development of cane rather than the application of available plant-food elements.

The same plant-food element may be applied in different forms of fertilizers to cane on uniform land and invariably there will result a difference in the yield from each of the different fertilizers, although they were all applied in the same quantities and all were in an available form. This leads one to inquire if it is not possible that certain of the substances or possibly a very small amount of some unsuspected foreign substance contained therein did not serve some other purpose than that of merely feeding the plant.

The human system often responds to the effect of very small quantities of certain chemical compounds. These supply the body with neither weight, heat, nor energy; hence they are not foods, yet they in some way spur the body on the greater action and for that reason are termed stimulants. It is possible, indeed quite probable, that there are elements and compounds which act as plant stimulants. For instance, it has been observed that when there is but a very minute quantity of certain soluble compounds of iodine applied to growing cane, in some way or other the maturity of that cane is materially hastened, while at the same time a marked improvement is made in the sucrose content and purity coefficient of the juice.

It is evident that the successful sugar planter who expects to maintain the fertility of his particular soil must be willing to devote endless study and research to his special plantation problems in order to discover nature's secrets in the proper handling of the soil. He should take nothing for granted nor assume that the methods followed by his successful neighbor will answer as well for his plantation. Indeed it has been shown that he will find it necessary to employ different methods even on the various parts of his own plantation unless the soil is extremely uniform.

POTASSIUM

This element, like practically all of the other elements used to any extent in the building of the tissues of sugar cane, does not appear in nature in the uncombined state but instead it is always found in compounds containing other elements.

Potash is the term commonly used to designate the chemical compound containing this element when reference is made to its presence in soils and fertilizers. This substance consists of a combination of two parts potassium and one part oxygen. Potash is one of the most soluble forms in which the element exists and it may be assimilated very readily by the cane.

Potassium is usually present in abundance in ordinary cane soils of the Philippines and only in exceptional cases has it been found necessary to make special applications in the form of fertilizers. In numerous cases applications of soluble forms of potassium have given excellent results notwithstanding the high potassium content of the soils as shown by a chemical analysis; but this was due to the fact that the potassium present was not in a form available to the cane. In such cases as the above, it is important that cultural conditions be maintained which will favor the disintegration and decomposition of the soil particles containing this element. Applications of lime in many cases have been advantageous in causing an interchange of the plant-food elements contained in soil particles with the consequent liberation of potassium in a soluble form. Similar results may be obtained by applying various other chemical compounds to such soils but lime is the safest material to apply.

Due to the fact that much of the potassium in ordinary soils exists in an insoluble form, it is not readily lost in the drainage waters, and, for this reason, it is found by chemical analysis that the percentage of this element is quite large. Low, boggy lands containing much peaty materials are, however, often deficient in potash. This is due to the fact that the potash derived from organic compounds is usually in a soluble form and consequently readily leached away and lost with the drainage waters.

There have been various theories advanced as to just what function potassium performs in the growth of plants but none of them gives a very satisfactory explanation. It has been observed that sugar cane when grown on lands containing but a limited supply of available potash invariably has a yellowish color and makes a very slow growth. The stalks are quite often shriveled up and poorly developed. This is no doubt because potassium in some manner performs an important office in the synthesis of starch, possibly in the transfer of this material or its incomplete forms from the leaves to the various parts of the plant. Moreover, when sugar cane is grown on soils containing but a limited supply of soluble potassium it becomes much more susceptible to various fungus and other diseases.

It has been stated that sugar cane contains approximately 1 per cent of potash. That portion which is present in the leaves and tops of the cane is returned immediately to the soil, after the crop is harvested, while only a limited amount of the remainder is lost from the soil if the ashes from the bagasse and the molasses or the lees from the molasses, in case this is converted into alcohol, are returned to the soil. If the by-products of sugar production are properly handled, the supply of potash from the previous crop is practically all in an available form for the immediate use of the succeeding one, only in the latter case a little more time is required to effect the decomposition of the compound and liberation of the potash.

It has been mentioned that certain lands are occasionally encountered which are deficient in potassium and for this reason applications of fertilizers containing this element in an available form will give good results. There are various forms in which this element is used in fertilizing material, among the more common being the chloride and sulphate.

In tropical countries like the Philippines, where there is a great deal of rainfall, the chloride often gives very good results, but in arid regions there is some danger of an accumulation of the chloride compounds, and an excess of this acts in a detrimental manner to many plants. But in tropical countries with the heavy rainfall which commonly occurs, it is possible to find soils quite deficient in chlorine. Since this is a necessary constituent of plants, being present to more or less extent in the leaves, it is therefore possible that under such conditions the chlorine of potassium chloride may act beneficially as well as the potassium.

PHOSPHORUS

Phosphorus, like many of the other elements found in soils, does not appear in nature in the uncombined state. It would not be desirable to apply this element to plants in such a condition even if it were possible, due to its extremely active qualities.

This element is present to some extent in all soils. It is also found in great deposits of rock-bearing phosphates, in the bones of all animals and in the mineral content of plants.

In the various rock formations it is usually present in the form of a calcium phosphate. The rock known as apatite, with the formula $3Ca_3P_2O_8CaCl_2$ or $3Ca_3P_2O_8CaF_2$, is particularly rich in phosphorus; and this forms a common source of supply of the phosphorus used in commercial fertilizers.

The phosphorus found in ordinary bones appears mainly in the tri-calcium state. This material is extensively used as a source of phosphorus in commercial fertilizers. The bones require treatment after being ground into small particles in order that the phosphorus may be reduced to a soluble form which is immediately available to such plants as sugar cane.

The widely different forms in which this element exists, each of which has a distinct solubility peculiar to itself, cause a great difference in its availability to plants. It has been previously remarked that in order for any element to be available to plants it must necessarily be in a soluble state. Some of the forms in which phosphorus is found are extremely soluble, hence they may be assimilated at once by sugar cane; but again they offer the disadvantage of being readily lost from the soil through leaching.

One of the most soluble forms of all is that of phosphoric acid, the formula of which is H_3PO_4. The anhydrous form of this substance contains 43.7 per cent of phosphorus.

Among the various forms in which phosphorus combines with calcium may be mentioned the mono-calcium phosphate, $CaH_4 (PO_4)2$, di-calcium phosphate, $Ca_2H_2 (PO_4)2$, tri-calcium phosphate, $Ca_3 (PO_4)2$, and the tetra-calcium phosphate, $Ca_4P_2O_9$.

The first-mentioned form is available to sugar cane because it readily dissolves in ordinary soil water and may be absorbed by the rootlets of the plant. On account of this fact it is often termed water-soluble phosphoric acid when referred to in commercial fertilizers. It is also called mono-basic phosphate, acid-calcium phosphate, acid phosphate of lime, acid phosphate, and soluble phosphate of lime. This form contains 60.7 per cent of the anhydrous phosphoric acid ($P_2 O_5$) or 26.5 per cent phosphorus. It is formed when calcium combines with the acid or where those forms containing more than one atom of calcium are treated with certain chemicals.

Di-calcium phosphate $Ca_2H_2 (PO_4)2$, sometimes called di-basic phosphate, citrate or acid soluble phosphate, reverted calcium phosphate, and secondary calcium phosphate, is soluble with difficulty in water and consequently this material is only available to a limited extent. This is a very safe manner in which to have phosphorus present in a soil, since it does not readily leach away and escape with the soil waters. At the same time it is available to a certain extent to sugar cane and through the agencies of acid waters in the soil and the oxygen from the air it is gradually changed into one of the more soluble forms. While it is advantageous to have the main store of phosphorus in the soil present in this form, there should be a limited supply present in one of the more soluble forms for the immediate use of the cane.

The tri-calcium phosphate $(Ca_3(PO_4)2$, sometimes called tri-basic phosphate, is insoluble in water and consequently it is of no practical value as a direct food for plants.

Like the di-calcium form of phosphorus and many other compounds containing plant-food elements, this substance slowly decomposes under soil conditions and the plant-food material is gradually liberated, although it requires a much longer time than is necessary for the di-calcium form.

Tetra-calcium phosphate, $Ca_4P_2O_9$, is sometimes known as tetra-basic calcium phosphate or tetra-basic phosphate of lime, also Thomas phosphate, Thomas slag, basic slag phosphate, or basic slag phosphate of lime. This material is extremely insoluble and is useful to plants only after it has been subjected to special treatment. It contains approximately 39 per cent of anhydrous phosphoric acid or 17 per cent of phosphorus.

It will be seen that phosphorus is present in soils and various fertilizing compounds in widely different forms and many of these compounds possess entirely distinct characteristics. Where it is desired to purchase this element for application to soils deficient in available phosphorus, it is important to select a soluble form and apply only the required amount to obtain results in the most economical manner.

If a chemical analysis shows the soil to be well supplied with phosphorus and yet experimental plots on which soluble forms of phosphorus was applied show increased yields from the use of this fertilizer, it is evident that the phosphorus of this soil is present in an insoluble form. Cultural methods should in this case be employed that will cause the soil particles to be decomposed in order to liberate the phosphorus. This requires that the soil be well aërated in order that the oxygen from the air may assist in breaking down the chemical compounds. An abundant supply of organic matter should also be incorporated in the soil. This furnishes a medium in which soil bacteria may live and the acids given off during the decomposition of these organic compounds assist in the decomposition of inorganic soil particles.

It has been remarked that conditions may be maintained in the soil favoring the liberation of plant-food elements. Likewise under adverse conditions it is possible for the soluble forms of these elements to be changed to those which are insoluble and of little direct benefit to the plants. As an example of this class, may be mentioned where phosphorus is present in an available form and heavy applications of lime are given the soil. In such a case it is possible for the compound of phosphorus under certain conditions to combine with the lime and change it to an insoluble form. This will explain why it is not safe to mix fertilizing material containing certain chemicals nor even to make extremely heavy applications of lime to certain soils where immediate results from all of the plant-food elements within that soil are desired. The familiar chart shown in Fig. 3 indicates graphically the fertilizing compounds which may be mixed with safety and which ones should never be brought into close proximity.

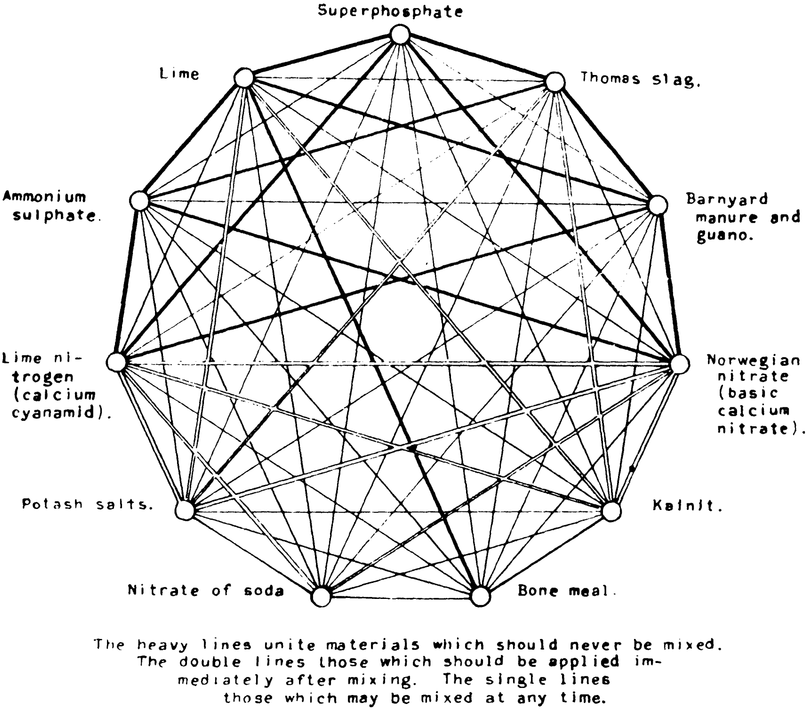

Superphosphate
Thomas slag.
Lime
Ammonium sulphate.
Barnyard manure and guano.
Lime nitrogen (calcium cyanamid).
Norwegian nitrate (basic calcium nitrate).
Potash salts.
Kainit.
Nitrate of soda
Bone meal.
The heavy lines unite materials which should never be mixed. The double lines those which should be applied immediately after mixing. The single lines those which may be mixed at any time.

FIG. 3. Fertilizer chart.

Where proper conditions are maintained in the soil and the by-products from cane production and sugar manufacture are properly returned to it, there should be an abundant supply of phosphorus available for the cane at all times on those plantations which were originally well supplied. There are exceptional cases, however, where the soil is composed mainly of materials deficient in phosphorus or in which the phosphorus was in a soluble form and has leached away.

Under such conditions the application of materials containing this element will give beneficial results. The explanation on the chemical compounds containing phosphorus should guide planters if they find it necessary to purchase this element in commercial fertilizers. Where such material is purchased, it should be borne in mind that immediate results must be obtained and with that end in view the soluble forms only should be employed.

NITROGEN

This is one of the most abundant of all of the necessary plant-food elements. It composes approximately four-fifths of the atmosphere. Here it exists in the uncombined or free state and above each hectare of land there is estimated to be present nearly eighty-six thousand tons of pure nitrogen. In this condition, however, it is of little practical value to sugar cane; but through the medium of bacteria which thrive in the root nodules of leguminous plants the nitrogen may be changed into various chemical compounds and deposited in the soil. In this manner it becomes available to nonleguminous plants such as sugar cane.

Nitrogen, like many other plant-food elements, is present in various compounds in the soil and in fertilizers. Not all of the nitrogen contained in this material, however, is available to sugar cane, and some of the forms even appear to be more or less toxic to that plant. It is important that an ample supply of nitrogen in the favorable forms be present in order to obtain best results in cane production. Such plants as the sugar cane can best use nitrogen in its nitrate form which readily dissolves in water and is directly available to the cane. It is thought that nitrogen in the form of ammonia is available to a limited extent to sugar cane but this is not considered as the most satisfactory form for use on sugar plantations.

Nitrite is quite different. This substance is entirely unsuited to the growth of such plants as sugar cane, since it acts as a plant toxin or poison. The useful forms of nitrogen may be changed into this form under certain adverse conditions and thus become detrimental rather than beneficial to sugar cane.

Nitrogen has often been classed as the limiting factor in soil productivity. Few plants can get along without this element and yet it is extremely fugitive when in a soluble form, so that it is readily lost from the soil. In the first place this material is easily dissolved in water and may escape from the soil through leaching. Again there are classes of bacteria which destroy nitrogen compounds and thus liberate that element. Nitrogen is usually the most expensive of all of the necessary plant-food elements when purchased as a fertilizer and yet it is the one most easily provided if proper crop rotation is practiced. The other plant food elements are derived entirely from the soil and it is never possible to increase the supply, however carefully the plantation work may be conducted, without the application of material bearing these elements from other sources. The very best that any planter can do is to provide conditions in his soil favorable for the gradual liberation of these elements for the use of his crops. The case is quite different with nitrogen, as there is an unlimited supply of this element available in the air and, as has already been explained, the destruction of nitrogen-bearing compounds through denitrifying bacteria, decomposition through burning and other means, cause quantities of nitrogen to be again liberated and restored to the air, so that the supply therein can never become materially reduced, much less exhausted.

In view of the unlimited supply of nitrogen at the command of the sugar planter, there is seldom any need of buying this element in the form of fertilizers provided that a proper system of plant rotation and cultivation is practiced. It has been explained that it is a comparatively easy task to deposit this material in soils by the aid of legumes and it is practically as easy to guard the supply from unnecessary losses by leaching and denitrifying bacteria if proper attention is given to cultural methods. In the discussion on soil bacteria the first problem will be explained, while the latter is discussed under soil drainage.

Fig. 4 indicates the cycle through which nitrogen passes in its course from the free nitrogen of the air to bacteria, thence to plant substances, and from this material to animal substances, and thence back to the soil. If conditions suitable to the growth of the beneficial organisms are maintained, the greater portion of this material will be changed to a form suitable to the cane and it will be gradually liberated as needed. On the contrary, if adverse conditions should prevail, the nitrogen will be changed to a form detrimental to the cane or it may even escape entirely from the soil as free nitrogen. There are bacteria of various classes present in all soils and those soils which are extremely fertile are usually found to contain these minute organisms in

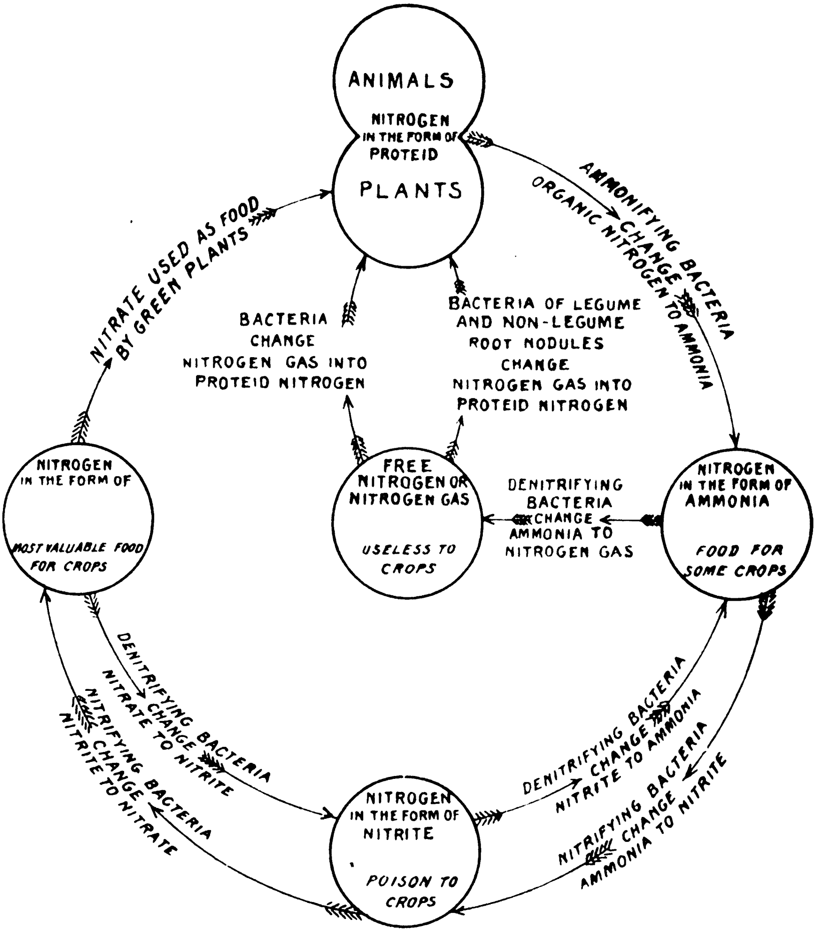

ANIMALS
NITROGEN IN THE FORM OF PROTEID
PLANTS
NITRATE USED AS FOOD BY GREEN PLANTS
AMMONIFYING BACTERIA CHANGE ORGANIC NITROGEN TO AMMONIA
BACTERIA CHANGE NITROGEN GAS INTO PROTEID NITROGEN
BACTERIA OF LEGUME AND NON-LEGUME ROOT NODULES CHANGE NITROGEN GAS INTO PROTEID NITROGEN
NITROGEN IN THE FORM OF
MOST VALUABLE FOOD FOR CROPS
FREE NITROGEN OR NITROGEN GAS
USELESS TO CROPS
DENITRIFYING BACTERIA CHANGE AMMONIA TO NITROGEN GAS
NITROGEN IN THE FORM OF AMMONIA
FOOD FOR SOME CROPS
DENITRIFYING BACTERIA CHANGE NITRATE TO NITRITE
NITRIFYING BACTERIA CHANGE NITRITE TO NITRATE
DENITRIFYING BACTERIA CHANGE NITRITE TO AMMONIA
NITRIFYING BACTERIA CHANGE AMMONIA TO NITRITE
NITROGEN IN THE FORM OF NITRITE
POISON TO CROPS

FIG. 4. Nitrogen cycle chart

greatest abundance. While the fertility of soils does not depend entirely upon these bacteria, they perform a very important function and the mere fact of their existence is in itself evidence that organic matter is present and suitable cultural conditions obtain.

Among the bacteria found in soils which are of special interest in conserving a supply of nitrogen are two general classes; namely, the *aërobic*, or those which flourish only in the presence of air, and the *anaërobic* or those which live in the absence of air.

The aërobic bacteria are largely responsible for maintaining the fertility of many soils by liberating nitrogen so that it may be used by plants. They change the pent-up nitrogen of organic compounds to an available form. Even the nitrogen present in many organic fertilizers must be acted upon by bacteria before the sugar cane can use it. It may be seen that this class of bacteria perform a very important function on sugar plantations; and since they exist only in the presence of air and act on organic compounds, conditions favorable to their activities should be maintained by the planter. This will include proper aëration of the soil thorough cultivation and drainage, and the presence of suitable quantities of lime to keep the soil neutral and loose, in addition to the maintenance of a constant supply of organic matter. Another class of bacteria of interest to the planter are those responsible for depositing the free nitrogen from the air in the nodules of leguminous plants. When suitable conditions are not maintained within the soil, the denitrifying or anaërobic bacteria are able to thrive. These, instead of fixing nitrogen in the soil, liberate that which is already present and return it to the air or change it to a form that is toxic to plants. So it is a poor practice to permit such conditions to exist in the soil that this type of bacteria will thrive.

While the exact function of any one plant-food element in plant development is rather difficult to define, yet the importance of nitrogen in the growth of sugar cane is quite apparent when it is realized that practically every portion of the plant contains certain compounds in which nitrogen plays an important part, though the amount of it present may be small. One of the most important effects of nitrogen noted in the growth of sugar cane is that produced in the foliage of the plant. Other conditions being favorable for growth, an abundant supply of nitrogen in an available form will cause the leaves to assume a rich green color. This in itself is an indication of strong, healthy growth. On the contrary a lack of nitrogen or its presence in an unsuitable or toxic form will give the cane a yellowish, sickly appearance and the growth will be slow.

Sugar cane is a plant which instead of sending up but one stalk, as is observed with ordinary farm crops, produces a great number of stalks, due to the development of the buds on the rhizomes of the root-system. This veritable forest of cane that is produced annually requires a great surface area in its leaves in order that the function of respiration may go on properly; and while it requires a balanced ration of all the necessary plant food elements to account for the proper development of the plant, there is no one element the function of which is more noticeable in this respect than nitrogen. This element likewise affects the age of maturity of the plant. It is a common belief among sugar producers that a supply of nitrogen in the soil will delay the maturing period of the cane and cause a reduction in the purity of the juice to result; but it has been the writer's experience that a suitable supply of available nitrogen, along with the proper amount of the other necessary plant food elements, other conditions being favorable, will cause equally as high or even higher purities to result than is possible where this element is lacking in the soil. This was proved in the experiments conducted at the La Carlota Experiment Station during three consecutive years.

As regards the use of this element in safeguarding the health of plants, it has sometimes been remarked that insects and plant diseases affect sugar cane less where there is a large supply of nitrogen present in an available form. But in the writer's opinion any one element alone is able to accomplish little in this direction. As mentioned before, there must be a properly "balanced ration" of all the necessary plant-food elements in order to keep the plant in a strong, vigorous condition and thus able to withstand adverse treatment.

CALCIUM

This is one of the most common of all the necessary plant-food elements and forms approximately one-sixteenth of the material making up the earth's surface. On account of its active qualities while in the pure state, it is always found in combination with other elements. It ordinarily exists in the form of calcium carbonate or limestone and great deposits of this material are found in various parts of the earth where the rock is quarried for economic purposes.

The deposits are either of sedimentary, transported or organic origin. Sedimentary rock is deposited when calcium in one of the active forms meets with carbon dioxide, causing a new chemical compound, calcium carbonate, to be formed. Since this material is quite insoluble it is precipitated out of solution and deposited as more or less pure calcium carbonate. The island of Romblon contains vast deposits of sedimentary as well as coral limestone which is extremely pure and will answer very well for the production of lime not only for application to soils but for clarification of cane juices as well.

Transported limestone is deposited by such agencies as winds and the flow of water. In this case, the rock is usually ground into small particles and deposited in heaps of loose material like that on the eastern coast of England which has furnished such valuable material for neutralizing the acids and loosening the heavy soils upon which it has been used for centuries.

Great limestone deposits of organic origin also exists in many places. These consist of the mineral remains of animal life such as the crinoids, corals, and mollusks which existed during by-gone ages when the lands were submerged.

Calcium, in one of its common forms, namely, oxide, hydroxide and carbonate, performs very important functions in maintaining the productivity of cane soils. These may be summarized as chemical, physical, and biological. It would be utterly impossible to grow a crop of cane if there were no calcium in the soil, since this furnishes an essential constituent of the plant; yet it is seldom if ever necessary to apply fertilizers containing this element, for most lands are abundantly supplied for that purpose. In the production of each ton of cane there is removed from the soil approximately one kilo of calcium. This material need not be lost, however, since it may all be recovered from the ashes of the burnt bagasses and from the filter-press cane when the by-products of manufacture are returned to the soil. As in the case of the other necessary plant-food elements, calcium passes through a regular cycle, year after year, being first dissolved by the soil waters, then taken up by the rootlets of the cane, and carried to the various parts of the plant, where it has a vital office to perform in the elaboration of sucrose, though it does not become a chemical constituent of that substance. The cane is then cut, the juice extracted and the sucrose, a pure carbohydrate with no calcium in it, is recovered. The calcium in the juice passes on to the molasses and filter-press cake, while that contained in the fiber is deposited in the ashes during the combustion of the bagasse and the two are returned to the soil ready to perform this important function in crop production another year, thus completing the cycle.

Material containing calcium is so cheap and so readily accessible, and the improvement, physical and biological, of soils treated with compounds of this element is so great, that it would be very poor policy to make calcium the limiting factor on a sugar cane plantation.

While sugar cane grows best on lands that have the proper amount of available plant-food material present, yet it is equally as important to maintain suitable physical conditions within the soil in order that all elements may be properly assimilated. Certain classes of clay soils form a plastic mass which is impervious to water, hence they are unsuitable for the growth of sugar cane until properly treated. Applications of lime on many of such soils will cause the soil particles to become granulated and assume a distinct form thus rendering the soil loose and porous.

The writer investigated clay soils on the Iwahig Penal Farm, island of Palawan, with the idea of employing them in the production of sugar. These lands had been planted to rice for several years but it was found utterly impossible to retain a supply of water over the rice fields within the bounds of the earthen dykes, notwithstanding the fact that this class of soil in which yellow clay predominates is usually very retentive. A chemical analysis showed the soil to contain over 5 per cent of calcium compounds which had caused a flocculation of the clay particles and made the soil so porous that the water readily filtered through.

In order to produce large crops of sugar cane there must be proper circulation of the soil waters. This serves to prepare a sanitary home for the plant by removing through gravity and capillarity the water polluted by the oxidation of poisons of the plant. In addition to this, the movement of soil waters serves to carry a supply of soluble plant-food material from remote regions to the rootlets to feed the plant. Calcium also renders many compounds harmless to sugar cane.

Every fertile soil is filled with minute organisms known as bacteria. These perform very important functions in giving life to the soil and in preparing plant-food material in an available form. That these bacteria may thrive the soil must be in a suitable condition. Lime serves to neutralize the acids and sweeten soils thereby accelerating the activities of the soil bacteria.

Applications of lime on soils consisting of fine sand and silty material may cause them to become more retentive by cementing together the soil particles. Such soils are thus better able to retain moisture during a prolonged drought and the capillarity of the soil is materially improved.

The form in which the lime should be applied, the amount to apply and the time to apply it for best results are important problems of the sugar planter's.

Calcium may be applied to cane lands in any one of the three aforementioned common forms, the oxide, hydroxide, or the carbonate, with equally good results; provided that not too much of the first-named form is applied at a time when the land is well supplied with organic matter, and that it is not placed in close proximity to growing plants. Where the carbonate form is employed, it is necessary that more time be given it to act;

hence it will give best results on soils which require lime more for the future than for present needs. The oxide and hydroxide forms give the quickest results and at least a limited amount of one of these should therefore be employed on extremely toxic soils in order to obtain prompt results. These, however, or at least the oxide, present the disadvantage of destroying the organic matter and thus may cause a loss of plant-food material, when applied in too large quantities. On account of the difficulty encountered in handling lime in the oxide form, the hydroxide or slaked form is usually preferred. This is prepared by leaving the lumps of burned lime in contact with the air for some time or by pouring water over the newly burned lime and leaving it in the air for a while, which causes it to swell up and crumble into a fine powder. The carbonate is the safest form to use as it may be applied to all classes of soils and plants without danger of destroying the organic material; but it is slow in action, and can be used to advantage only on certain classes of soils.

The writer has obtained the best results in the use of lime on the majority of cane lands of the Philippines by making light applications of the oxide or hydroxide which is thoroughly incorporated in the soil. This is followed by a second and heavier application, using the carbonate form. A sufficient amount of the oxide should be added to neutralize the excess of acid and there is usually required for this at least 200 or 300 kilos and sometimes more per hectare, depending upon the amount of acid and other neutralizable toxic substance in the soil. Applications of lime in the form of carbonate should be made at the rate of two tons or more per hectare if it is desired to improve the mechanical condition of the soil as well. Usually it is more profitable to make a few heavy applications than numerous light ones.

ORGANIC MATTER OF CANE SOILS

It has been remarked that soils are composed of inorganic or mineral matter and organic matter.

The term organic matter refers to the tissues of both plants and animals. In the case of plants this material consists largely of cellulose, which is derived mainly from the carbon dioxide of the air and from water, while the small amount of mineral matter and nitrogen in plants are derived from the soil.

The application of organic matter to soils acts in a beneficial manner by supplying extra plant-food material, and in assisting in the liberation of plant-food elements from the rocks and soil particles. In addition to this it improves the texture of most soils, serves to retain moisture and provides a medium in which bacteria may thrive.

When organic matter becomes thoroughly decomposed it forms the dark-colored material known as humus. This contains the remains of the plant and animal tissues which are broken down by the process of oxidation, whereby the plant-food elements contained therein are liberated for the use of the plants.

The diagram in Fig. 4 indicates graphically the cycle through which nitrogen passes in being changed from the free nitrogen of the air into living forms of plants and animals, later deposited in the soil and finally returned to the air or re-entering plant and animal tissues. When organic matter is decomposed and converted into humus, various acids known as humic acids are given off. These act upon the rock particles in the soil and liberate plant-food elements in the same way as would result if one of the stronger acids were applied to the rock particles, except that the process is slower. This is one of the wise provisions of nature to gradually liberate the plant-food material, little by little, as required by the plants, while at the same time the main supply is left in an insoluble form which is secured from the loss that would result from leaching.

The sugar planter who would learn the secrets of nature in maintaining soil fertility on his plantation needs only to go into the forest and there he will find a great carpet of organic material is deposited year after year. The lower portion of this mat has long since turned to humus and now forms the habitation of countless minute organisms that are ever busy in preparing material to feed the plants. Virgin soils, which are universally classed by planters as being the most productive sugar cane soils, have been formed in this manner. The process by which they were formed seems extremely simple when nature alone is intrusted with the task, but when the land is cultivated and crops are produced year after year there is often noticed a gradual decrease in fertility due mainly to the fact that few planters profit by the example set them by nature and follow her methods. When a crop of sugar cane is harvested there is left remaining on the field a heavy coat of leaves and tops consisting mainly of organic matter like the mat of leaves found in the forest. After this material is decomposed humus is formed from the organic matter which is valuable to the plantation. It is the ruinous custom among planters of the Philippines to burn off this mat of leaves and trash after harvesting the cane in order to facilitate cultural operations. This treatment causes the *organic matter to be entirely lost* to the soil. While it is true that the land may be cultivated with less difficulty when this material is thus removed, there is experienced at the same time a fatal loss of the important organic material which would have enriched the soil. It will be shown later that the production of a soil is largely measured by the bacterial activities taking place within that soil and these are entirely dependent upon the supply of organic matter present.

It has been remarked that only carbon, hydrogen, and oxygen, elements of the air, and water are employed in the elaboration of sucrose in the form of finished sugar; the small amount of ash removed with the crop of cane may all be returned again as one of the by-products of sugar production. It seems unreasonable that the fertility of the cane soil would be impaired greatly by crop production if proper methods were followed to conserve all of the by-products. In the first place there is no less than ten per cent of the crop left on the soil in the form of tops and leaves of the cane. This is equal to the organic matter deposited yearly in many forests. If this material were left on the surface to decompose or were mixed into the soil it would perform almost as valuable a function in enriching the soil as the heavy coat of leaves do in producing the rich virgin soils of the forest. In addition it would serve to protect the soil from the burning rays of the tropical sun and thus prevent the loss of the nitrogen and moisture which are so badly needed on all sugar plantations. So long as this system, common in the Philippines, or burning off the leaves and trash after the harvest of the cane and throwing away the waste products at the factory, is practiced the organic matter in the soil will continue to diminish until the soil is similar in appearance to a mass of mineral matter like brick and cement. Such a soil is in a dead condition, so to speak, and can never make a suitable home for any plant. Cane grown on such soils will have a bad color and yield smaller returns than would be possible on the same soil under favorable conditions, however, thoroughly the cultural methods may be executed and however well prepared the soil may be.

It has been observed that cane soils containing a supply of humus from the previous crops are invariably in a better physical condition and therefore respond better to cultural operations than those without it. In comparing the cost of producing cane under the two systems, it must be taken into consideration that where the organic material is destroyed more irrigation water is required to replace that lost through evaporation by the sun and the heat engendered by burning the trash; valuable nitrogen is lost through the destruction of the organic compounds containing same and, in addition, it is impossible to maintain suitable conditions for the development of the bacteria which give life to the soil. All of these items are important and more than counterbalance the extra labor necessary in preparing the soils obstructed by this trash. It has been the writer's experience that ratoon crops produced with trash left upon the ground require less than one-half as much cultivation as that required on the burned fields, and that a better stand of cane invariably results. One of the essentials in the development of the rhizomes of sugar cane is to have a moist, loose soil about the root system. This condition can be maintained most readily where there is shade over the ground such as that produced by a heavy coat of cane leaves and by having incorporated in the soil a supply of organic matter and humus.

SOIL BACTERIA OF CANE LANDS

The subject of micro-organisms in soils is very important to sugar planters, for these organisms are largely responsible for the fertility of various soils. Soil bacteria may be considered as the connecting link between plant and animal life and indeed it is through their activities that the tissues of various plants and animals are broken down and the plant food material is converted into a form to be used by the plants. It is these minute organisms that give life to the soil and prepare a suitable home for plants.

There are an astonishingly large number of bacteria present in soils. Not all of these, however, act favorably in their enrichment but the majority of them are beneficial. It has been found that upwards of 50,000,000 of these bacteria are often present in a single cubic centimeter of fertile soil where conditions were favorable for the development of the bacteria and the production of plants.

It may be readily understood why the surface soils are often highly fertile and the sub-soil is apparently in a dead state and fails to produce large crops, when it is considered that the greater percentage of the micro-organisms and approximately 65 per cent of the total nitrification occurs in the upper thirty centimeters of the soil, 30 per cent in the next half meter, while beyond that depth very little of this important work of intrification goes on.

Experimenters have found that crop yields are usually proportionate to the number of bacteria present in the soil, and that the lands most plentifully supplied with humus or decomposed organic matter contained soil bacteria in the greatest abundance, while those fields containing the lowest percentage of organic matter had the smallest number of bacteria. It has been conclusively proven that an abundant supply of available nitrogen is necessary in the production of large cane crops and that bacteria are largely responsible for fixing this material in the soil. It is therefore evident that the problem of providing a suitable medium in which the nitrifying bacteria may exist should be given serious attention by the sugar planter.

Among the numerous classes of bacteria found in soils, may be mentioned two which deserve particular attention. One of these is responsible for changing plant-food material to a soluble form which is suitable for plants, while the other has the power of transforming soluble forms of nitrogen into a form unavailable to plants.

The first type, or *aërobic bacteria*, exists only in the presence of air and thereby obtains the supply of oxygen required in bringing about the transformation of the nitrogen in the soil. The other class derives its oxygen from that contained in organic compounds which it causes to be broken down. This class of bacteria is known as *anaërobic bacteria*. Since one of these classes of bacteria acts in a beneficial manner and the other acts detrimentally to the soils, the problem of maintaining the conditions in the soils favorable to the beneficial class should be given attention. It is therefore obvious that the first step is to have the soil in a well aerated condition. Anything which increases the porosity of the soil permits the air to enter in great volume and favors the growth of these bacteria. This condition of the soils also permits the entrance of sunlight and consequently causes the soil to be warmed, which is beneficial to the growth of the bacteria. It is for this reason that cultivated lands are in a better condition for the growth of the beneficial class of bacteria than lands which lie fallow.

The application of lime often assists in improving conditions for the development of bacteria by sweetening the soil and causing granulation or flocculation of the soil particles.

Nitric acid is one of the compounds resulting from the activities of the aerobic bacteria and when the nitrates become too abundant the conditions are unfavorable to the growth of these bacteria, while at the same time they become favorable to the denitrifying form, which have the power of changing the nitrates into nitrites, ammonia and even free nitrogen, so that it becomes unavailable to plants. The action of lime on soils heavily laden with nitric and nitrous acid serves to produce salts of these acids and improves conditions for the nitrifying bacteria.

Another thing of importance is to provide a suitable medium in which they may live. For this purpose it is important that humus be present in abundance. As explained under organic matter, this may be supplied by growing and turning under various crops and by returning to the soils the various by-products from sugar plantations. One of the best materials to use is filter-press cake from the modern factories. In regard to the application of molasses for this purpose it has been rather a disputed question as to just how much value may be attributed to this material. The writer has experienced that on many of the well drained lands of the Philippine Islands extremely encouraging results were obtained when this material was applied in the irrigation water, at the rate of two to three tons per hectare; while on those which suffered from improper drainage, as well as on lands the acidity of which had not been properly neutralized, the material was detrimental rather than beneficial. The analysis of average exhausted molasses shows that the nitrogen content is a little more than one-half of one per cent and the total ash content but slightly greater. The low percentage of these fertilizing elements would indicate that any increase in crop yields did not come from these fertilizing elements alone but rather from other sources, since the application of these elements in such small quantities in any other fertilizer fails to give appreciable results. Extensive experiments have been conducted in Mauritius with this material and it was found that an increase of upwards of twelve tons of cane per hectare was obtained up to the third ratoon. This would indicate that on those soils the effect of this material might be noted for a long time.

It is presumed that molasses acts more as a soil renovator and performs other functions than only that of supplying the plant-food material it contains. It is not improbable that the residue from the carbohydrate material present furnishes a suitable medium for the beneficial or nitrifying bacteria on the well drained soils. It is to be presumed that the effect of molasses on the development of nitrifying bacteria may be of a similar nature to that performed by sugar as described in Berthelot's experiments.

Where molasses is employed as a soil renovator, precautions must be taken in its application, since this material may have a detrimental rather than a good effect. It has been pointed out that in soils where the nitrifying bacteria are active the denitrifying class are at work as well; and while some of the conditions are favorable to both alike, yet there are others which are directly antagonistic to the development of the latter class of bacteria even though they favor the former. Since an abundant supply of oxygen is essential to the activities of the former, and detrimental to the latter, it follows that molasses will give the best results on well aërated soils. It also follows that it would not be well to apply this material to lands which have their nitrogen in the form of nitrates, as this form is readily acted upon by the denitrifying bacteria, and this causes the nitrogen to be lost from the soil.

It has been explained that although plant tissues may be well supplied with the various plant food elements this material is entirely locked up from the use of other plants until liberated by the aid of nitrifying bacteria. The planter is in fact indebted to this class of bacteria to convert the plant-food elements into available form in such fertilizers as tankage, cottonseed meal, bone meal, and copra meal and indeed even in stable manure, and filter-press cake. It is fortunate that he can control conditions, however, so that the class of bacteria which act favorably to the plants will predominate over the denitrifying or unfavorable class.

Nitrogen is the plant food element most easily lost in nature through leaching and this is especially true with reference to the Philippines during the rainy season. It may also be liberated and escape in the free state through the decomposition of the various compounds.

The amount of nitrogenous matter consisting of albuminous bodies, pectin, and the like contained in cane averages from 0.5 to 1 per cent. The nitrogen in this case is derived entirely from the soil, since sugar cane is not a nitrogen gatherer.

DETERMINATION OF REQUIRED PLANT-FOOD ELEMENTS AND SOIL TREATMENT

It is not an easy task to ascertain what plant-food elements will give best results on a soil and the proper treatment that soil should receive. To determine these factors it is necessary to carry on numerous experiments and devote endless study and attention to the work.

There are certain general characteristics noted in the growth of plants that may indicate the presence or absence of a sufficient amount of any element. Since these conditions are altered by various physical, chemical and biological conditions in the soil as well as by climate conditions, little dependence can be placed on definite rules. Where other conditions are favorable, however, a pale-green or yellow color in the cane leaves, and a slow growth and spindly appearance of the stalk are evidence of the lack of nitrogen. Conversely the presence of an abundant supply of available nitrogen causes the foliage to assume a rich green color, the growth to be accelerated and the cane to present a thrifty appearance.

A deficiency of phosphorus may be noted in the growth of sugar cane but since growth also depends upon so many other conditions it cannot be relied upon as a sure indication of a lack of that element.

Potassium serves an important purpose in some manner or other in the elaboration of starch within plants, so a shortage of this material may possibly be known by the appearance of the plant tissues.

The only system of determining whether or not there is sufficient available plant-food material present and what would be the best to employ there in order to obtain maximum results is to perform experiments on different parts of the plantation using various combinations of fertilizers, or if the land of the plantation is uniform, it will be sufficient to perform this work on separate experimental plots.

PLANT FOOD ELEMENTS IN FERTILIZERS

The problem of having available adequate quantities of soluble plant food material for the production of large crops of sugar cane has been given much attention on many plantations of the more advanced sugar countries and in some cases very beneficial results were obtained from the use of commercial fertilizers. It is a matter of common knowledge among agriculturists that there must be present in the soil in an available form a certain amount of each and every plant-food element in order that the plant may grow well. It matters not if there are present stores of all the elements except one; the size of the crop that is produced will be determined by the amount of that one element missing. It constitutes the limiting factor in the productivity of that soil. The tub consisting of many unequal staves illustrated in Fig. 4 is intended to represent the available plant-food material in the soil. If all of these staves, which represent various elements, are sufficiently long, thus indicating a proper supply of each element, the soil would be considered as extremely fertile and a balanced ration of the plant-food elements would exist. If, however, one of these is extremely short though the others are sufficiently long; i. e., even if the other elements are present in various amounts acocrding to the necessity of the crop, the fertility of that soil will be measured according to

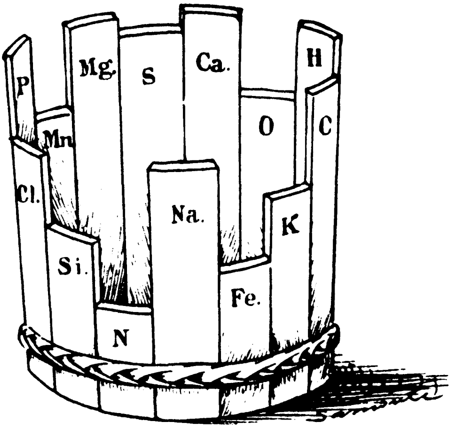


FIG. 5. Sketch showing limitation of plant food elements

this element constituting the limiting factor, and the size of the crop the soil is capable of producing will be determined likewise. It is not possible for the elements which happen to be present in superabundance to completely fill the place of those which are deficient, though possibly this may be done to some extent.

In order to place a store of available plant-food elements at the command of the plants, fertilizers may be resorted to. First of all the planter must be informed of the limiting factor in the productivity of his soil so that he may apply only those elements which are deficient. This is somewhat difficult to determine but unless it is done the money spent for fertilizers may be entirely thrown away. A chemical analysis of the soil will be of immense value in this respect. Further increasing the supply of the already over supplied elements for the immediate need of the crop, while those which are deficient in the soil are not provided in adequate quantities in the fertilizer, is no doubt largely accountable for the poor results often obtained with fertilizers on many plantations. The practice has certainly resulted in needless expense and is one that may never bring returns on the investment, since by the time the element would be required, due to the partial exhaustion of the original supply from constant cropping, it may be changed into another form that is entirely valueless to cane.

It has been explained that chemical changes are being made continually in the soil and while some plant food elements are being liberated others change to an insoluble form.

It is the duty of the sugar planter to see that the immediate needs of his crop are provided for. The surest guide is to conduct some experiments on the various part of the plantation, using different combinations and amounts of the various plant food elements.

Fig. 2 indicates a simple method of laying out the plots and conducting the experiments. If the task were completed when the amount of the particular element or elements that are deficient was ascertained, the problem would not be so difficult; but then it becomes necessary to know the economical limit in the application of the deficient element. That is why further experiments must be conducted using different quantities of each element.

Once the proper fertilizer combination is decided upon for each particular soil the future problems are to secure the fertilizer in the most economical form and have the plant food elements present in chemical combinations that will be beneficial and directly available to the cane. Lastly it is important to apply the fertilizer in such a manner as to make it most effective. While sodium nitrate will give excellent results on some lands, ammonium sulphate or perhaps one of the numerous organic fertilizers containing nitrogen may give better results on other lands. The same may also be said of potassium.

Usually a fertilizer that is produced in the country where it is used will be found the cheapest, since fertilizers consist of very bulky material and therefore cause heavy expense where transportation problems are involved. In some regions of the Philippine Islands bat guano has been found. This material has given fair results when applied in large quantities although it contains a lower percentage of plant-food elements than that found in other countries, due to the leaching away of these elements by the heavy torrential rains.

The average analyses of this fertilizing material found here is as follows:

Nitrogen 2 per cent, potash 2 per cent, phosphorus compounds 8 per cent, lime 9 per cent.

To make the fertilizing material most effective it must be placed within reach of the plant rootlets in order to be utilized; and for that reason it is best to make an application consisting of one-half of the total amount to be applied in one year at the time of planting. After the furrows have been prepared for the points, the fertilizer should be spread at the bottom of these furrows and a small shovel plow passed again through the furrows to mix the fertilizer with the soil. The points thus planted, the furrows are partly covered and irrigation water is applied.

After the cane is about half grown the second application of fertilizer is made, this time it is thoroughly worked into the soil near the cane stools during cultivation.

In the case of ratoon cane it is best to make one application at the time the first cultivation is given and the soil from near the stool is being exchanged for new soil from between the rows. The second application is made after the cane is about half grown, as in the previous case. It must be borne in mind that no fertilizer material is of value to sugar cane until it is dissolved in the soil waters, so that it may be taken up by the plant rootlets. This is why emphasis must be placed on proper methods of irrigation in conjunction with fertilizers if a prolonged drought is likely to follow the application.

Since air and heat as well as moisture exert important effects upon results of the plant-food elements in fertilizers, it is important to have this material placed to the proper depth in the different soils. In sandy soils, which soon lose their water through drainage and evaporation, the fertilizers should be placed to a lower depth than would be necessary with stiff clay soils. Such fertilizing materials as sodium nitrate and ammonium sulphate are readily dissolved and carried downward by the soil waters. With organic fertilizers the case is quite different. The plant-food elements in these are usually more secure from the effect of water and these materials must undergo important changes before they will give up their plant-food elements. For this reason it is important to have these materials placed deeper in the soil than would be the case with those which are soon dissolved and readily carried downward by the soil waters.

Special fertilizer combinations are often recommended for sugar lands in general. One that has given excellent results on certain lands consisted of—

5 per cent nitrogen from ammonium sulphate.
15 per cent potash from potassium sulphate.
12 per cent phosphoric acid.

Applications were made consisting of from 100 kilos to 500 kilos per hectare.

It has been the writer's experience that distinct compounds are required for each particular land to be treated. The fact that each crop of sugar cane removes from the soil specific amounts of each plant-food element, depending upon the size of the crop, does not necessarily imply that the soil is bound to be in need of these elements in exactly that proportion. Soil requirements are determined not only by the quantity but also by the form in which each element is present in the soil. If there was a large supply of certain elements present in a form that would be readily made available, any increase by way of commercial fertilizers would no doubt result in a financial loss to the planter.

In a word, it can not be too strongly emphasized that before fertilizers are employed on a commercial scale extensive experiments should be conducted and the chemical formula for a fertilizer applicable to that particular soil ascertained.

SOIL MOISTURE

Sugar cane is a plant which requires much water in the elaboration of its various component parts. This is due to the fact that immense quantities of cellular tissues are constructed where a crop of upwards of a hundred tons are produced on each hectare of land. It has been found by research on numerous occasions that only about five-tenths of one per cent of the material in the plant consists of mineral matter, while the remainder is composed largely of the elements carbon, hydrogen and oxygen. The first named element, carbon, is derived almost entirely from the carbon dioxide of the air; but the others, hydrogen and oxygen, come from water. These two elements are present in the form of water in the various compounds with other substances dissolved therein, while in other cases they are present in entirely different chemical compounds but in the exact proportion necessary to form water. Sucrose, for example, has the formula $C_{12}H_{22}O_{11}$, or 12 atoms of carbon, and hydrogen and oxygen in sufficient quantities to make exactly eleven molecules of water.

When sucrose is decomposed by such common agencies as enzymes, heat, and acids, each molecule combines with one molecule of water, with the result that invert sugar is formed. The following formula indicates the chemical reaction which takes place:

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} = \underset{\text{Dextrose}}{C_6H_{12}O_6} + \underset{\text{Levulose}}{C_6H_{12}O_6}$$

Although the form of the resulting invert sugar is changed from that of sucrose, the ratio of the two elements for the formation of water remains identical.

In the synthesis of various compounds such as sucrose within the plant, it is evident that water performs an important function not only in conveying inorganic plant food material to all parts of the plant but that it also becomes an integral part of those issues as well. Another important function performed by water is that of removing the waste products of the plant. If these were not removed to a proper distance from the plant or destroyed by the action of other compounds, they woud act as plant poisons.

While a certain amount of water is taken in by the leaves of the plant, the greater quantity is absorbed through the roots, where the necessary inorganic elements and other dissolved material, including gases, are conducted to the plant as well. Since water performs such an important part in the production of sugar, care is exercised on all well regulated plantations to have the necessary amount within reach of the plant.

Water is present in soils in three forms; namely, *hydrostatic, capillary,* and *film.* Hydrostatic water is the water which runs off the land after showers or percolates through the pores of the soil and seeks its level through the power of gravity. It is this water which drainage aims to dispose of, for it would otherwise leave the soil in such a heavy condition as to make it unsuitable for cane.

Capillary moisture is that water which is held in the pores of the soil and moves upwards to the surface by the force of capillarity; in this manner it acts as a vehicle in carrying dissolved plant-food materials to the roots of plants. This water is responsible for keeping the ground moist and supplying plants with water even during the driest season. The mechanical condition of a soil governs to a large extent the amount of capillary moisture that will be brought to the surface. In this respect the soils act in a manner very similar to a lamp wick. The more porous the material from which the wick is made the more readily will the oil be drawn up to the surface by capillary attraction. This operation of bringing water to the surface continues until it is no longer removed as fast as it reaches the surface; that is, until a condition of stable equilibrium is reached. Since it is not desirable to deplete the supply of capillary moisture by permitting this water to escape into the air through evaporation, it is a good practice to maintain a mulch of fine earth over the surface of the soil which is more or less compact. This practice is especially beneficial in conserving moisture during a markedly dry season.

Water in the form of hydroscopic moisture is not available for the use of plants, because it adheres very closely to the soil particles; yet it performs an important function in dissolving plant-food elements in the soil particles and making them available to plants. All soils are supplied with more or less moisture in this form even though there may be but little present in any of the other forms.

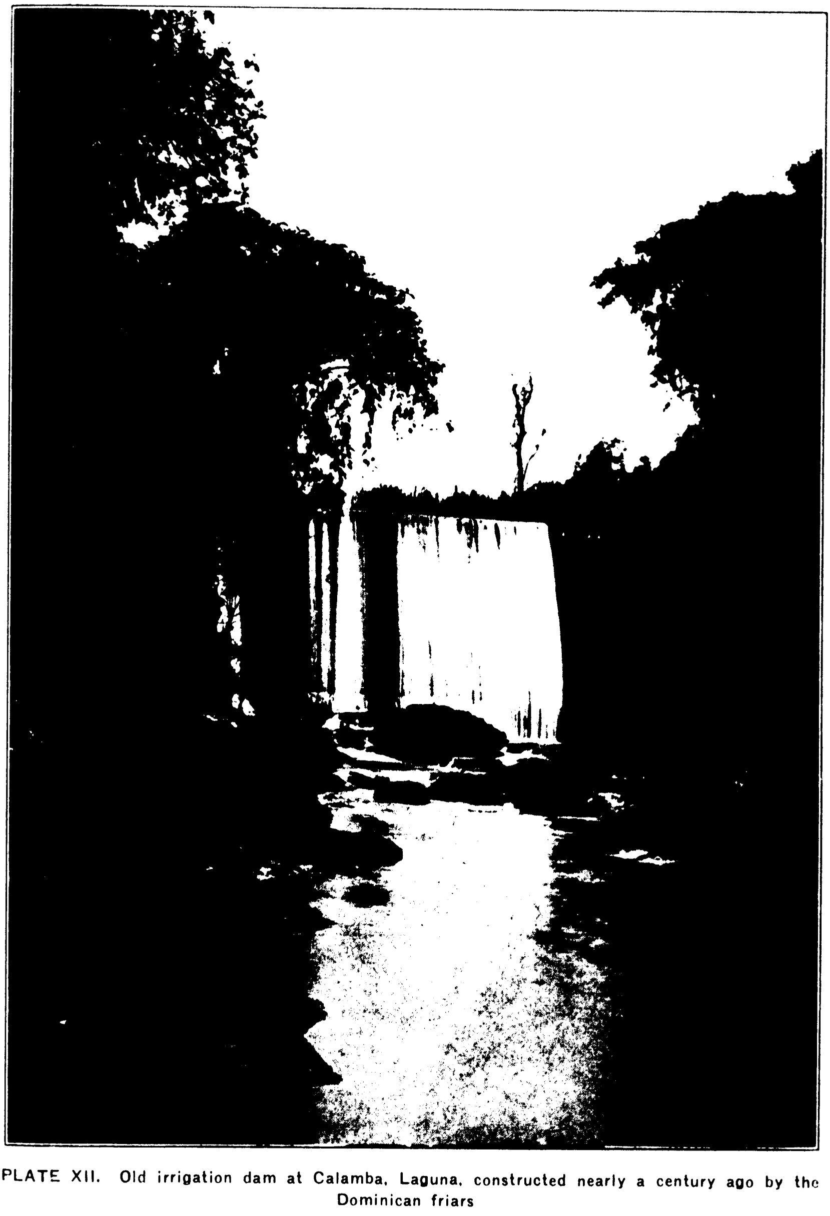


PLATE XII. Old irrigation dam at Calamba, Laguna, constructed nearly a century ago by the Dominican friars

IRRIGATION

In countries where there is a distinct dry season extending over a considerable portion of the year or where there are intermittent rains and markedly dry spells, there is nothing that will give such remunerative results in the growing of sugar cane as occasional applications of irrigation water, if they are made at the right time, and in the proper manner, and if the water is applied in the necessary amounts. In tropical countries the water on the surface and that present in the top stratum of the soil may soon escape, due to the intense rays of the sun and the dry winds that so often prevail; hence the growing crop may soon suffer for want of water if due provision is not made to guard against this. It is true that proper cultural methods and the maintenance of a mulch of fine earth over the surface of the land will prevent the escape of moisture, and thus conserve the supply already present; but if this store is insufficient to last over the period of drought, or if the soil is of such a nature that the supply of water is soon exhausted through sub-drainage and excessive porosity, it will be necessary to augment it by such artificial means as the case demands.

The condition of the growing cane is the very best guide to show the needs of the plant. A yellowish, sickly appearance, check in the growth of the plant and shriveled leaves, all serve to indicate a lack of water, though they are not considered absolute guides, since a deficiency of the necessary plant food material in an available form and the presence of plant-toxins and other adverse agencies and conditions may be indicated by the same signs.

It has been explained under plant-food elements that it is not enough merely to have the necessary plant food materials present in the soil, but that these must be in a soluble form and actually dissolved in the soil water before they can be taken up by the rootlets and used by the plants. There is no doubt but that water performs the function of actually feeding this inorganic plant food material to the cane, while at the same time itself entering into the tissues of the plant, thus assisting respiration and providing for plant growth.

In the majority of cases water for irrigation purposes on sugar lands is obtained directly from running streams or from reservoirs formed by the construction of dykes across the stream to raise the level of the water. In some cases artesian wells are employed if there is sufficient water within a short distance of the surface. This latter method is usually attended with more or less danger, since excessive amounts of objectionable chemicals such as the black alkali, sodium carbonate, and white alkali, calcium sulphate, are quite often present in these waters. The chemicals accumulate in the soil in sufficient quantities to seriously affect the growth of such crops as sugar cane, after numerous applications of irrigation water have been made, unless there is sufficient rainfall during the year to redissolve then and drain them off. Where a limited amount of artesian water is employed each year, proper drainage facilities should in all cases be provided, so that the excess of water may be removed with dispatch instead of being allowed to settle in the lower lands, where it would evaporate, leaving its chemicals in the soil. After showers and during the rainy seasons, the excess of water in which is dissolved many of chemicals can be removed by the same drainage system. The only objection to this procedure is that the plant-food elements are also soluble and will be removed with the undesirable chemical compounds.

METHOD AND TIME OF APPLICATION

To repeat: It is extremely important that irrigation water should be applied to sugar cane in the proper manner and at the proper time. If a delay is made in its application after the cane has begun to suffer from want of water, there will be a check in its growth; while if the water is applied before it is really required, it will be worse than wasted, for it will actually injure the cane.

The manner of applying the water must be determined by the age of the cane, the method used in planting and prevailing conditions in general. When the land is extremely dry at the time of planting, a heavy application may be made to the soil just before the last stage in its preparation. The land is then furrowed out just as soon as it is sufficiently dry and the cane is planted and immediately covered with fine earth in order to retain the maximum amount of moisture. This method cannot well be practiced, however, on rolling land.

Where the land can be properly prepared without an application of water, it is usually better to apply it after furrowing out. In this case the water is let into the furrows already prepared for the cane, the points are planted, and, if the land is to be fertilized, the first application of the prepared fertilizer is made in the furrow just before the cane is covered. This permits a mulch of fine earth to be made over the surface of the land, which not only prevents the escape of moisture but also keeps the soil from baking. The succeeding applications of water are made in the same manner until the furrows are filled in with the loose earth. After this it is necessary to apply the water by means of a small furrow near the rows which is formed during cultivation.

FREQUENCY OF APPLICATION

The number of applications to be made is determined entirely by prevailing conditions. The class of soil, the manner in which it was prepared and cultivated and seasonal conditions, all have a direct bearing upon this subject. It is the general custom wherever irrigation water is employed to make the applications too often rather than not often enough. In some instances, it has been thought by growers of sugar cane that an application of water would take the place of cultivation; hence the water was applied oftener than would otherwise have been done. This is a very great mistake, as many planters have learned. In fact applications of irrigation water will cause weeds and grass to grow profusely and the top soil may run together and become hard. This demands more attention to both weeding and cultivation. If the top soil is dry it is not necessarily an indication that water should be applied, provided the land was prepared to a proper depth and the points were planted sufficiently deep; for there will be a store of water within reach of the rootlets during a period of three or four weeks after the first application. At this time, only a limited amount of water is necessary, for the young cane requires very little. After the cane reaches a

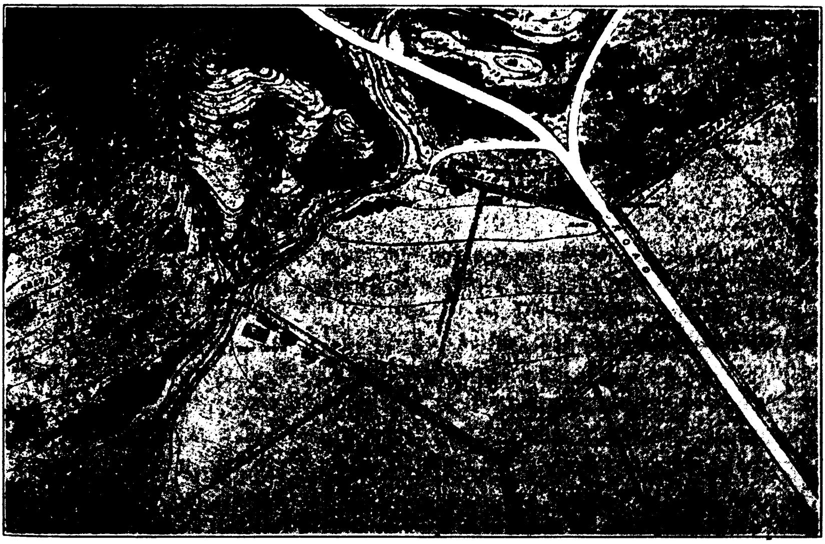


FIG. 6. Bird's-eye view of irrigation system

height of one-half meter, it needs more water, due to the development of numerous stalks; from there on it will require much water for its proper development.

In the case of ratoon cane, the first application of irrigation water should be made soon after the previous crop has been harvested, in order to put the land in good condition for the off-barring and cultivation that are to follow. If the leaves and trash are left on the ground and finally worked into the soil, the irrigation water will assist in the decomposition of this organic material and its conversion into humus.

LAYING OUT THE LAND

Where the land is nearly level, with only a gradual fall, it is a very easy matter to lay out an irrigation and drainage system, but where it is rolling the task is much more difficult.

First it is necessary to determine the contour of the region. This is best done by an experienced irrigation engineer, who uses his transit in determining the altitude over given areas. It is possible, however, for the planter himself to do this work if he has had some little instruction in èngineering, provided the land is not so rolling as to make the task over difficult. When the contour of the region to be irrigated is known, a large map is made and the location of the irrigation and drainage canals themselves are plotted thereon. Fig. 6, a bird's-eye view, shows the scheme that may be followed in irrigating a large sugar plantation. The plantations cannot always be irrigated by a gravity system, but where there is an abundant supply of water it is sometimes feasible to irrigate the higher regions by the aid of pumps. While this system is more expensive than the former, it offers the distinct advantage of permitting the utilization of all the water employed, since this is entirely absorbed on the various cane lands before it reaches the lower levels.

CARE OF THE CANALS

Irrigation as well as drainage canals should be kept in good condition during the entire year. If this work is neglected there will result a loss of irrigation water and an ineffective use of what is employed, while in the case of drainage the crop may be made to suffer from an excess of water. After the system is properly installed, it is well to encourage the growth over the banks of the canals of some perennial grass, as the bermuda. This will furnish pasture for animals which may be utilized when the canals are dry and at the same time it protects the sides of the canals from erosion. Unless the land near the canals is covered with such grass, the various weeds peculiar to that region are bound to thrive and their heavy stems will clog the ditches, thus retarding the flow of water, while the weed seeds will be carried down stream and distributed over the lands in the lower regions. The various gates in the irrigation system should likewise be given attention, so that the flow of the water may be properly controlled. It is usually the most economical in the long run to set these firmly in cement masonry. Where this is not feasible, wood may be used; but it must be wood with good lasting qualities.

DRAINAGE

However important it may be to have the required amount of water present for the production of sugar cane, it is equally as important to guard against an excess of water; for there are few farm crops which suffer ill consequences from an excess of water to a more marked degree than sugar cane. The tiny rootlets which tip the ends of the main roots as well as those from their side branches are very soft and delicate. These appear to suffer first of all; for they become water-logged, so to speak, and fail to properly perform their function of conducting water to the main roots, which are already filled with water and refuse to accept that which they have absorbed for starting on its course through the plant. By reason of this stagnant condition, the water becomes laden with the impurities given off by the plant, and as result it is more or less toxic. The plant then becomes "sick" from this poisoned material. This is manifested by the yellowish color of the leaves, the lack of vitality, and the check or even entire cessation of growth. It is no wonder that the plants can never entirely recover from such adverse conditions of growth, however well they may be treated later on.

Because of the very destructive effects of even one "drowning," it is highly important that proper attention be given to drainage on every plantation before the crop is planted. It has been observed on the majority of plantations that though an excess of water is detrimental to the growth of sugar cane at any time during its growth, yet that at no time during the life of the plant is it so destructive as during the first month or six weeks of its life, when even the main roots are young and tender and hence suffer almost as badly as do the very porous root tips during advanced stages. Still another advantage of preparing for drainage in advance of cultivation on many plantations is that of preventing the land from "puddling" in the various low places where the water would otherwise stand. The proper drainage of these places will permit the soil to be prepared earlier and quite often labor may be employed in this work at a time when it would otherwise be idle.

The laying out of the drainage system should be entrusted to a competent engineer whenever possible; but if for any reason such a person cannot be secured, the work should be done by some one who is familiar with the conditions on the plantation and who is able to handle a transit; for if it is improperly done, there will result poor drainage and an unnecessary waste both of land and of the labor employed in the building and upkeep of the ditches.

Various forms of closed drains, such as the underground tile canals, have given satisfaction in the United States and other countries, but these are not generally used in tropical lands, at least on sugar plantations; for while this system offers the distinct advantage of economizing in land and labor, it offers disadvantages as well, especially on sugar plantations containing a soil laden with silt where the ditches become clogged and filled up, which condition causes great trouble. Due to the dense vegetation that grows in tropical countries during the entire year, there is greater chance for rootlets to enter through the cracks between the tiles and thus check the flow of the water so that silt and other sediment are deposited. Notwithstanding

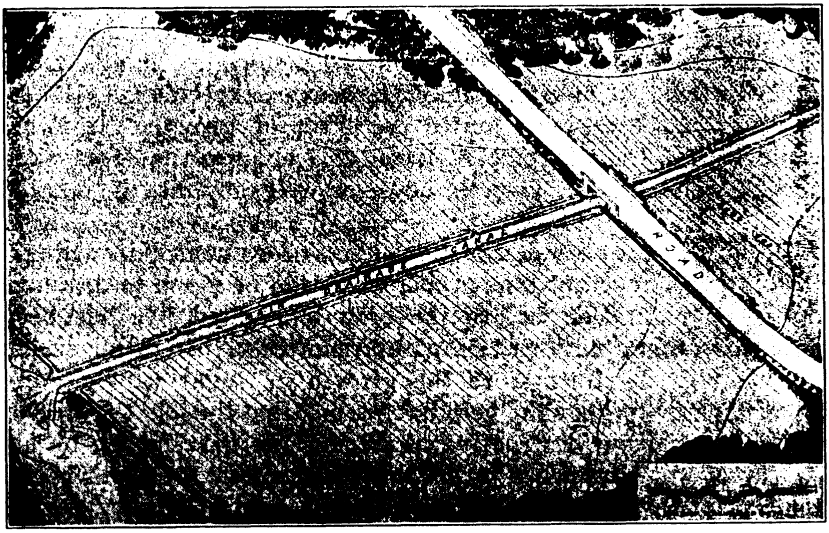


FIG. 7. Bird's-eye of drainage system

these drawbacks closed drains, as before stated, have proved efficacious on some plantations.

Whenever possible the main ditches as well as the smaller laterals should be run parallel with either the ends or sides of the fields. In many cases, this will eliminate the "short lands" and irregular fields and the resulting unnecessary loss of labor in preparing and cultivating such lands. Fig. 7 is a bird's-eye view of a drainage system on a sugar plantation.

While it is absolutely necessary to have a certain fall in the proper operation of ditches, it is important to guard against excessive fall, since the current thus accelerated has a destructive effect in wearing away the land. The lighter organic materials found in soils as well as the soluble inorganic material which is so valuable to plant growth is easily transported by the flow of

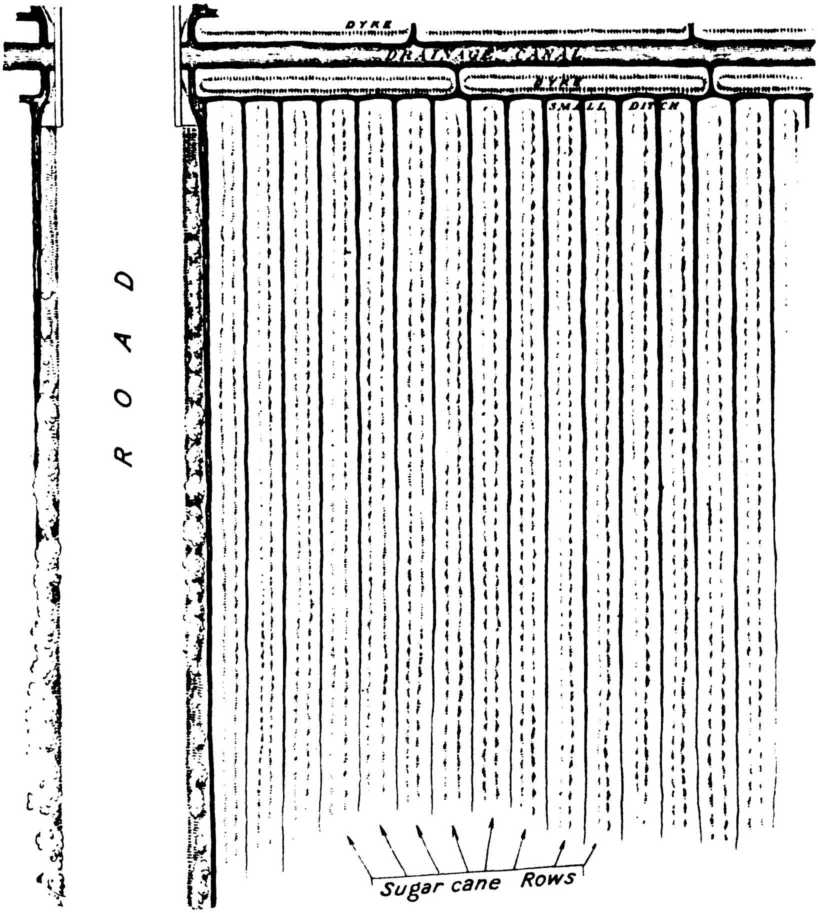
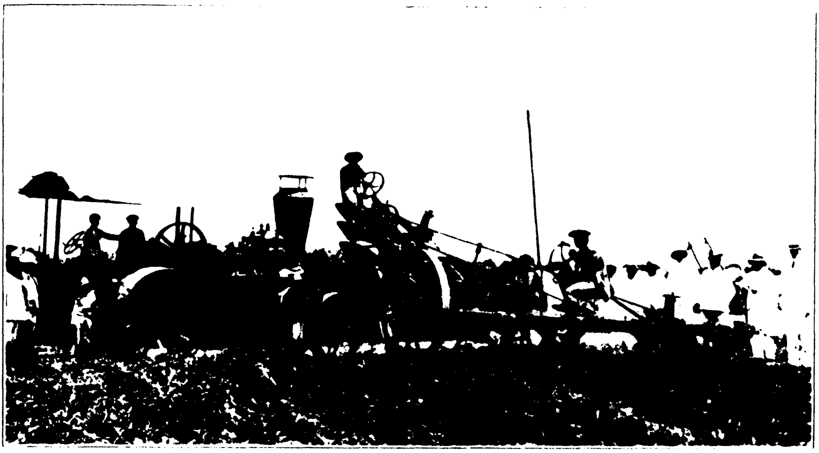


FIG. 8. Bird's-eye view of draining cane rows into main canal

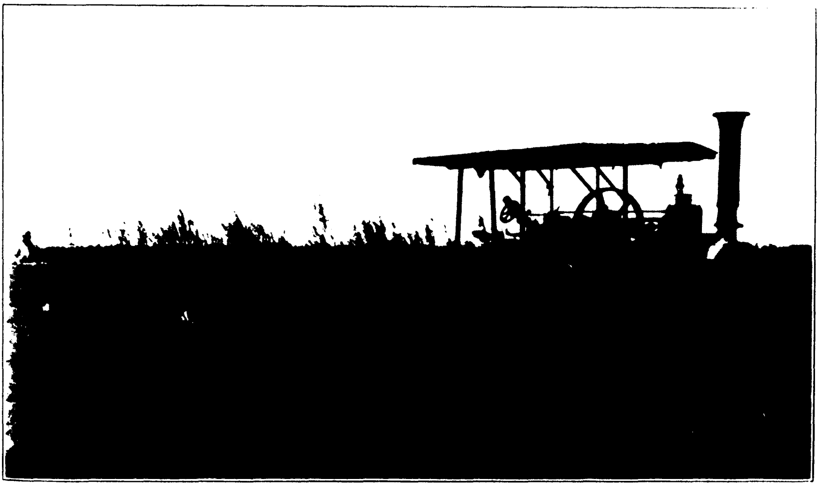
water, and this accounts for the valleys being particularly rich in plant food. If the water falling on cane lands is allowed to carry away this valuable material, the soil obviously will decrease in productivity year after year by reason of this unnecessary loss. Every possible means should be employed to check this flow not only in the ditches proper but also over the fields in general. The practice common on sugar plantations of opening the main furrows as well as the small furrows near the rows directly into the drainage ditch, results in an unnecessary loss of this valuable material and also causes deep gullies to be worn in the land, making cultivation difficult. The diagram in Fig. 8 shows a simple means of overcoming this difficulty. A small ridge is thrown up near the main drainage canal beyond the end of the rows which serves to check the flow of water from each individual furrow and divert it in a right-angled direction. After flowing for a short distance in this direction its course is again changed, this time into the main canal.

Where the land is extremely rolling it is not always possible to follow the straight line system as outlined above; in this case the contour system is used instead. This, in addition to conducting the water with the desired speed of current, serves the further purpose of catching the debris brought down from above. Where irrigation is practiced on the plantation, it is quite often possible to employ the same drainage canals during a portion of the year for the removal of excess of irrigation water, while in the rainy season they are employed to assist in carrying off the excess of water from torrential rains. In many cases the main irrigation canals proper may be made to serve a very useful purpose in this respect as well, if they have been properly laid out.

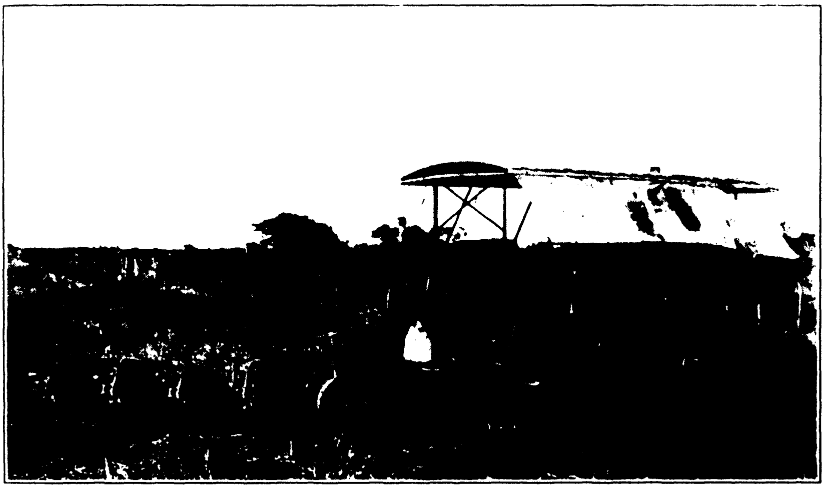
PLATE XVII. Plowing sugar land by carabao power



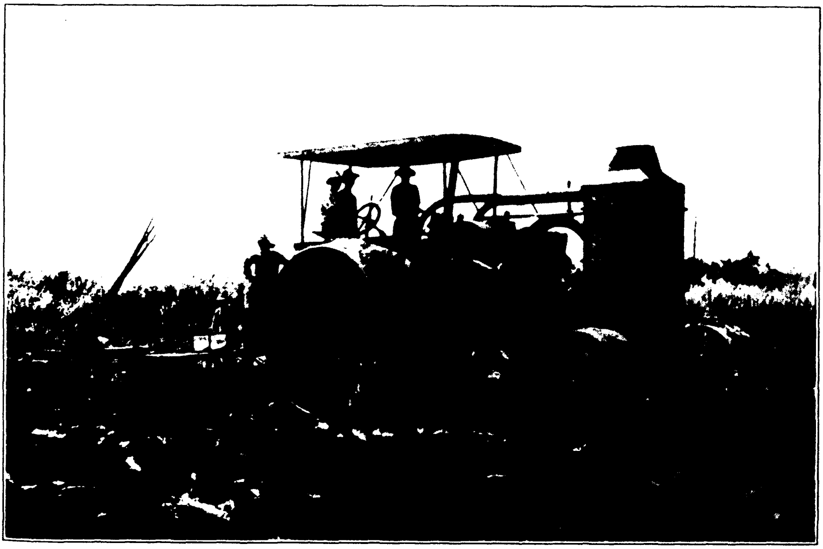
(*a*) Plowing land with two steam tractors attached by cable to a four-gang plow



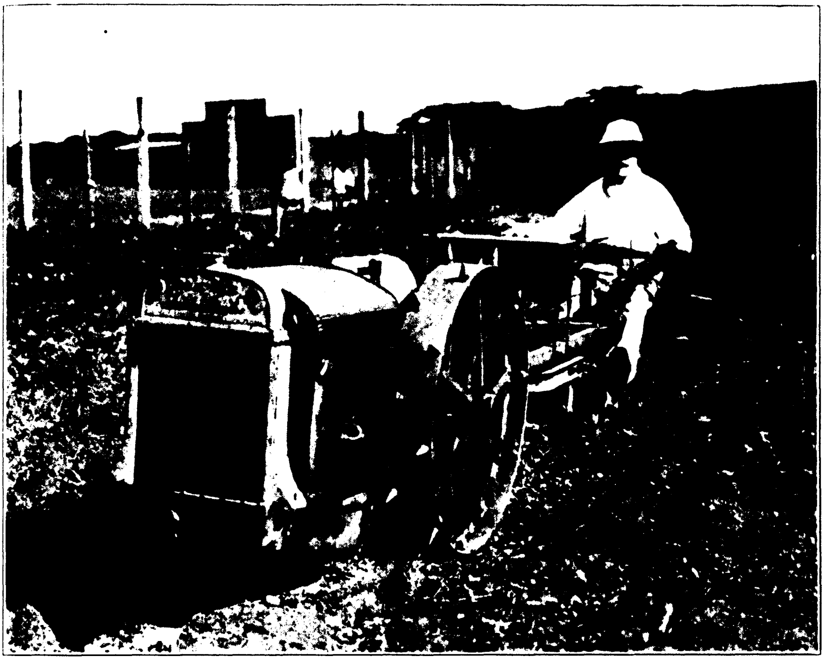
(*b*) Plowing land with two-disk plows drawn by a steam tractor



(*a*) Plowing land with disk plows drawn by Caterpillar tractor using either kerosene or distillate

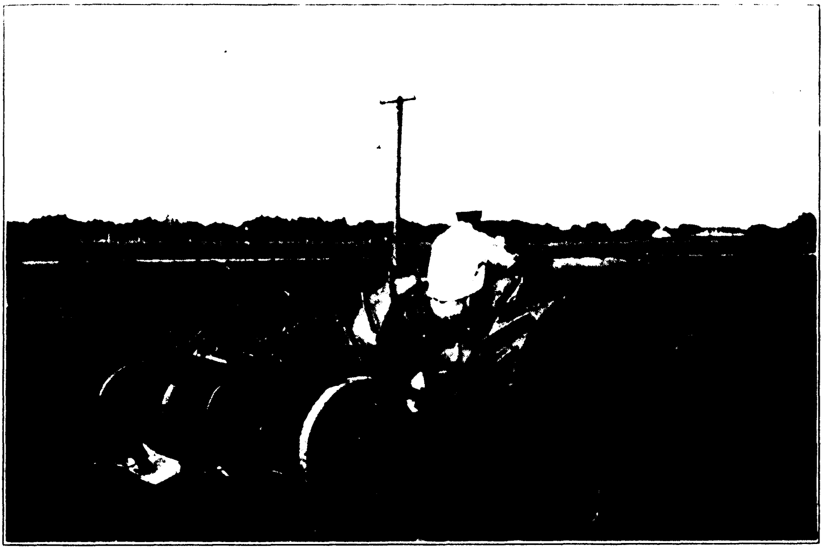


(*b*) Plowing land with large mouldboard plows drawn by tractor using either kerosene or distillate



(*a*) Special type of kerosene-driven tractor with plow attached

(*b*) Plowing land using a special type of tractor with a caterpillar tread. Either kerosene or distillate may be used as the motive power



(*a*) Kerosene-driven tractor used in preparing land on sugar plantations

(*b*) Kerosene driven caterpillar type of tractor used in preparing land on sugar plantations

(*a*) Special type of tractor using either kerosene or distillate as a motive power

(*b*) Kerosene or distillate driven tractor with a caterpillar tread and front wheel

TILLING OPERATIONS

It is recognized by agriculturists the world over that the immense crops which are harvested from many lands are largely the result of thorough and scientific tilling operations performed upon the soil. When sugar cane which is to ratoon for a number of years is to be grown, the proper execution of this work from the time the land is first broken is more important than it would be for almost any other crop, and so the work of plowing the land while there is no stubble or other obstruction to interfere can be done properly only during the preparation for cane planting. The work of preparing the land for ratoon crops consists mainly of shallow cultivation between the rows of old stubble.

The soil in its natural state is compact and more or less cement-like in appearance. It is so firm that the tiny roots of such cultivated plants as sugar cane find difficulty in penetrating to a proper distance both laterally and vertically in search of plant food material. In consequence of the poor tilth of such soil, the growth of the plants in curtailed, due to the small root system that develops, and a stunted appearance and starved condition result.

Another important purpose of tillage operations is to loosen up the soil so that air and light may penetrate to a depth sufficient to cause the various organic and some inorganic compounds to be oxidized and changed into forms available to plants. This same condition fosters the development of myriads of soil bacteria which give life to the soil, make available to plants the various elements already present, and prepare for their use the elements contained in organic compounds of both plantation by-products and commercial fertilizers. At the same time it serves to neutralize the effect of certain compounds in the soil that injure and may even cause the complete destruction of plants, by spreading these compounds, where they are too concentrated, over larger areas.

In stratified soils where there is a predominance of sand or clay, either of which in inimical to the growth of sugar cane, there is affected, by properly stirring up the soil, an admixture of these two constituents which often results in the formation of an ideal cane soil. Tillage operations put the soil into a favorable condition for the carbon dioxide of the air and various humic acids from the decay of organic matter to penetrate and come in contact with the various soil particles. This causes their decomposition and in consequence the liberation of valuable plant-food material. Where the land is well loosened up, capillarity is facilitated and water is transmitted from the lower regions to those parts within the radius of the roots. This not only provides some of the necessary constituents of the plant but, at the same time, it carries plant food material to the roots. It also serves the purpose of decomposing the insoluble material, as does the rain which percolates through the soil.

As an aid to the removal of excessive water from the soils, proper tillage plays an important part by improving sub-drainage. This is recognized as one of the simplest and best means of disposing of water and it serves another purpose also, that of removing plant toxins, thus assuring sanitary surroundings for the growth of plants.

PLOWING

The first operation in the preparation of cleared lands for sugar cane is that of plowing. On modern plantations the first plowing or breaking of the land is usually done by the aid of mechanical power, while in others, by horses, mules, cattle, or carabaos. Since the roots of sugar cane will penetrate to a very great depth in search of plant food and moisture if conditions are favorable, it is important that plowing be done to a suitable depth and this requires, in most cases, that the subsoil be thoroughly stirred up. While the depth to which the work of plowing should be done varies with the class of soil, on well regulated plantations, and where the condition of the soil will be thereby improved, it is loosened to a depth of at least fifty centimeters, or even more. If sufficient power is available a subsoiler may be attached behind the plow and run through the newly made furrow, tearing apart the firm under stratum and breaking it up, yet bringing practically none of this crude and undecomposed material to the surface. In Plate XX (a-b-c-d) various types of power plowing outfits are illustrated.

The proper method of plowing the land is to pass the plow near enough to the previous furrow that the entire new furrow will be cut and turned over and none of the unturned soil be covered, as would result if the furrow was cut too wide.

When sufficient time for the oxidation of soil material and germination of the weed seeds has elapsed after the first plowing, the land should be cross-plowed and subsoiled in the same manner as before. Where cable plows are available they will perform the first and second plowing and subsoiling operations in a very economical and satisfactory manner. The land is always very uneven and rough after the first operation, so that cross-plowing by animal power or by a tractor which drags the plow would be very difficult. This is why the cable plowing outfit should be employed in the second operation.

In many cases it will be advisable to plow the land the third time when sufficient time shall have elapsed for more weeds to germinate and the soil to require further stirring. Where the land is plowed more than once, it is necessary to run the plow at right angles to the last plowing. Since the land is loosened up and fairly well leveled after the second plowing, animals or small tractors will serve for the third plowing and the following operations.

Where the soil contains a desirable proportion of sandy material which makes it loose and easily cultivated, it is possible to prepare a good seed-bed with one or two plowings and subsoiling, followed, of course, by proper after treatment.

When the work of plowing is completed a disk serves as a good implement for pulverizing the moist earth. This may be passed either crosswise or in the same direction as the last plowing. Alternate operations with the harrow and either a smooth or corrugated roller should be continued until the top surface is well pulverized and free from large lumps.

FURROWING OUT

The land is then furrowed out and immediately planted before the moisture has an opportunity to escape. Where the large improved varieties of cane are planted, the rows should be spaced one and one half meters apart, but where the smaller native varieties are employed they may be spaced somewhat closer together. The furrows should be formed to a depth of from 20 to 40 centimeters, depending upon the class of soil and the future methods to be followed.

PREPARATION AND CARE OF CANE POINTS

It is the custom of sugar planters to extend the planting from year to year by means of points or cuttings of the green or immature portion of cane previously harvested. This system insures cane of identically the same variety as that previously harvested even though points of different kinds may be mixed together and planted indiscriminately in the same field. There is no danger of spoiling a variety and no chance of improving it by planting different varieties near each other, as many cane growers believe.

There are certain distinct characteristics peculiar to each variety of cane, such as the time at which it will mature, the

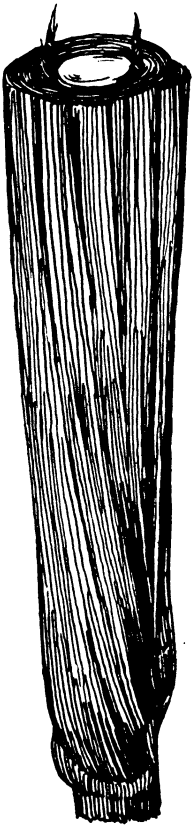


FIG. 9. Cane point properly cut

length of time the cane may be left standing after maturity is reached, the resistance to drought and excessive moisture, etc. In consequence the points of different varieties should be carefully separated at the time of harvest, and each variety should be planted alone. By this means cane best suited for milling may be cut at different periods during harvest.

It should be remembered that only the immature portion of the cane will serve as plant material. At harvest time, when the cane has reached full maturity, this will consist of the upper twenty or twenty-five centimeters of the stalk exclusive of the *last two or three joints*, which are too green to serve as plant material. In other words care should be exercised that the cane is *properly* topped and in no event should the end bud be left on the point. Fig. 9 shows a view of a cane point properly cut. In case planting is done early in the season, when the entire cane is yet extremely green, a number of cuttings may be taken from each stalk.

When the cane is planted early in the season while there is plenty of moisture in the soil and when there are frequent rains, the newly cut points may be "husked" and planted immediately without preliminary soaking, if favorable conditions prevail. But when the soil is dry and the cane from which the cuttings are taken is mature, it is essential that the points be properly soaked to induce germination of the buds.

SOAKING OF THE POINTS

Points should be soaked only in clean, fresh water; they must never be left where the water can stagnate. A river or running stream usually provides a suitable place for soaking the points. This may be arranged by means of a side channel to direct a small stream of water over the points. Where this is not possible vats may be used. In this case the water must be changed at least every twelve hours and preferably every six.

Cane points should be soaked in the manner above mentioned from thirty-six to forty-eight hours, depending upon prevailing conditions. They should then be thrown in heaps in a shaded place and covered with leaves and trash to await the operation of husking.

HUSKING THE POINTS OR REMOVING THE LEAF-SHEATHS

In this operation the leaf-sheaths which cover the buds are removed thus permitting them to grow out without difficulty. The points are then thrown in piles ready to be carted to the

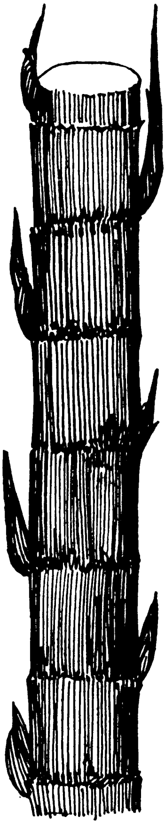


FIG. 10. Cane point after husking

field and planted. During this operation care must be taken to select only points with strong, vigorous buds for planting. It will be found that germination has been poor with the buds of some of the points. All such points must be discarded and only the good ones retained. This will insure a good stand of cane if the subsequent work of planting and cultivating is properly conducted and favorable growing conditions prevail.

Fig. 10 shows a cane point after soaking and husking.

PLANTING THE POINTS

The points should be planted in well-prepared, moist land. The furrows should be made immediately in advance of the planters to prevent the loss of moisture from the soil. They should be spaced about thirty centimeters apart where they are planted singly, and slightly farther when placed in pairs. Where fertilizers are employed the first application is made just

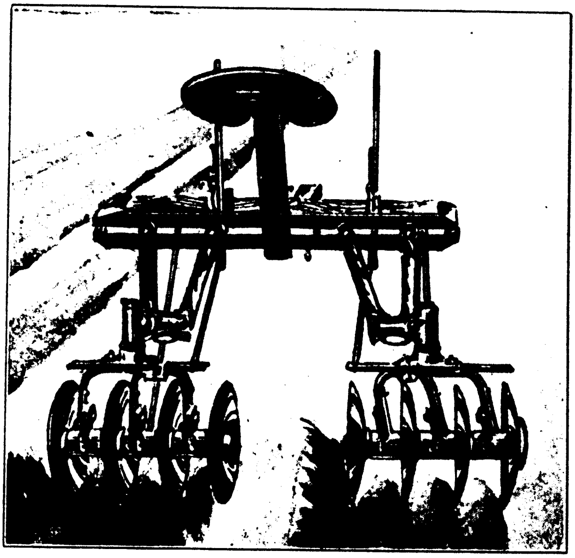


Fig. 11. Disk cultivator

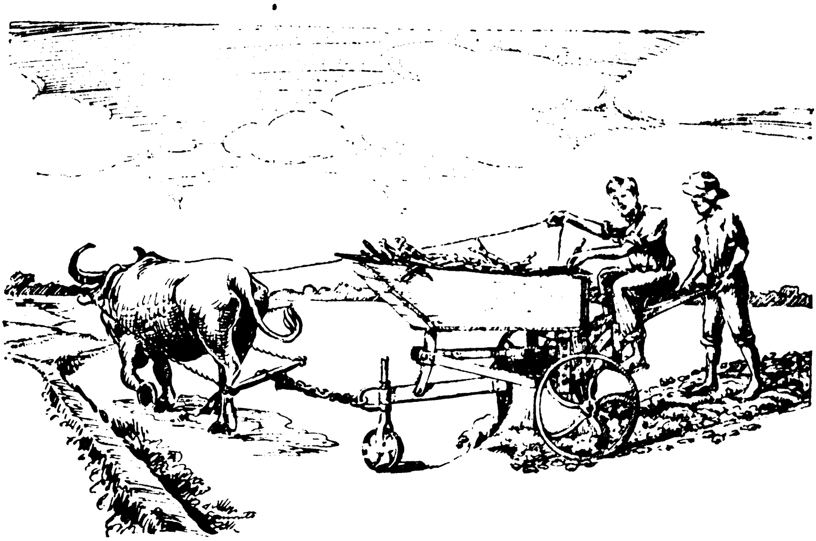


Fig. 12. Cane planter

before the furrows are filled in. The work of covering the cane may be done by a disk apparatus as illustrated in Fig. 11 or the points may be planted by an implement similar to the one illustrated in Fig. 12. The amount of earth employed in covering the points is determined by the class of soil and the methods that will be followed later. If irrigation water is avail-

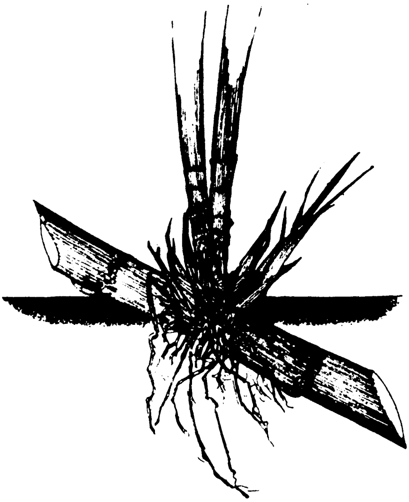


FIG. 13. Cane point six weeks after planting

able, the first application is made when the cane is planted, after which a light covering of earth is thrown into the furrow.

Fig. 13 shows a view of a cane point six weeks after being planted. The water having been applied, another small covering of earth is made to serve as a mulch and keep the soil from baking. When planted the points should be immediately covered with fine earth, which may be packed about them to prevent the escape of moisture.

During the progress of planting, they should be carted from the shaded place where they were being kept to the field, as fast as they are needed. They should not be left to lie in the sun for any length of time or become dry, as this would seriously impair the vitality of the new growth or plant. It should be remembered that the same rental, expense of preparing the land, planting, and cultivating will be required whether a large or small crop is harvested and that the size of the resulting crop is largely determined by the "stand of cane" or number of plants per unit area.

PLATE XVIII. Transporting cane points to field

PLATE XIX. Field of properly planted sugar cane

CULTIVATION

There are various implements which have an important place in the cultivation of sugar cane and the choice among them will depend on the particular class of soil to be cultivated as well as the state of growth of the cane. A light sandy soil may often be cultivated with a disk implement or a cultivator containing three or four small shovels; but a heavy soil will usually require a large cultivator. While the cane is small the cultivators may be run very near the rows and the work should be done to a depth of 20 centimeters or even more. As the cane develops and large brace roots are thrown out, care must be exercised that they be not disturbed. At this time the work of the cultivating may be more shallow and farther from the rows. By the time the cane is to be given the third and fourth cultivations, the roots will have spread out laterally. Small shovel plows may be used at this time and the earth is thrown towards the cane, which operation causes a ridge to be formed along the rows. This strengthens the cane and permits it to resist storms better than it could under flat cultivation, while at the same time the depression between the rows serves as a drainage ditch to remove the excess of water. Where a field of cane is prepared in this manner there is less danger of the crop suffering from an excess of water and at harvest time little decline will be noted in the sucrose content and purity of the juice during prolonged wet spells. The time at which the cane should be "laid by" is determined by prevailing conditions. As a rule it is not good policy to cultivate cane after it gets so large that it will be broken down by the animals when they pass between the rows.

Irrigation water should be applied periodically as required and the first applications should be made in the furrows over the cane, after which some fine earth is filled in to form a mulch over the top. When the furrow is completely filled in, the water may be applied in the depression between the rows. In this case it is made to spread and thus saturate the entire surface by banking the furrows at regular intervals and holding the water until it has time to penetrate the soil in all directions.

Where a second and third application of fertilizer is employed this material may be applied in the rows over the cane just previous to cultivation. Care should be exercised to have this well mixed with the soil or covered with earth before irrigation water is applied, since it would otherwise be washed away and deposited in places where it was not required.

It is thought by some planters that three applications of fertilizer should be made: the first at the time of planting, the second after the cane reaches a height of ½ meter and the third just previous to the rainy season. Others make two applications: the one at the time of planting and the other just previous to the rainy season, while still others apply all of the material at one time, during the first or second month of growth.

It has been the writer's experience that the three-application method will give best results in many cases and more particularly on lands with loose soils that leach badly and also where very soluble forms of the plant-food elements are applied. But where the soil is more or less impervious and organic or other forms of fertilizers are used, equally as good results will be obtained by the one-application method.

TREATMENT OF RATOON CANE

After the previous crop is removed, sufficient irrigation water should be applied to saturate the soil well. All leaves and trash are then drawn between the rows and work of off-barring and stool-cutting is done. It is essential that the soil near the stools be thoroughly loosened up and a portion removed to the middle of the rows and replaced by fresh soil. The old roots have finished their service to the plant and many of them are already dead, so these may be cut or torn away without any injury to it. The rhizomes, or underground stems, furnish the material for the future plant, consequently every provision should be made for the proper development of the eyes or buds on their internodes. While this operation is being performed, a portion of the fertilizing material that is to be applied either in the form of plantation refuse, such as press cake and manures from the corrals, or commercial fertilizers should be well incorporated in the soil near this mass of underground stems. Where labor is scarce the work of returning soil to the stools may be done by the aid of either small shovel plows or disks. During the off-barring the trash which occupied the space between the rows is covered with dirt; this assists in its decomposition and the preparation of humus for future crops. If the first cultivation of ratoon cane is well done, the future work will be simplified and the cane will be given a good start from the very beginning. The future care of the ratoon crop consists of alternate cultivations and irrigations, except during periodical showers, when the irrigation may be omitted. After four or five months of growth the second application of fertilizers may be made, and before the rainy season sets in provision must be made for proper drainage. Too much stress cannot be placed upon the immediate removal of excessive water during this season of the year; a soggy condition of the soil is fatal to the cane, as can soon be seen by the sickly appearance it will present. After the cane reaches such a height as to make cultivation difficult, it may be laid by or given only occasional weedings and hoeings.

HARVESTING

Sugar cane should not be harvested until it reaches complete maturity, at which time it will have the maximum sucrose and minimum glucose content and yield a juice of the highest purity. Composite samples of the cane from each field should be taken to the laboratory, from time to time, and analyzed when harvesting is about to be started. The juice in this case is extracted by the aid of a hand mill and reported on the form as in the model on page 122. When it is observed from the purity coefficient and glucose ratio that the maximum yield of marketable sugar will be obtained from that particular cane, the work of harvesting should be started. Several machines have been invented which may succeed in solving the cane harvesting problem but these are still in the experimental stage and as yet can not be recommended to handle fallen and twisted cane like that so often encountered in the tropics. In consequence the work of cutting and stripping the cane is still done by hand.

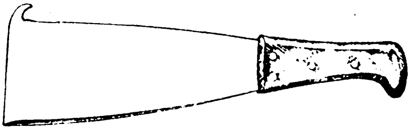


FIG. 14. Harvesting knife for sugar cane

The best knife for use in this work is one with a wide blade terminating in a hook at the top as illustrated in Fig. 14. This knife is approximately 50 cm. over all, and the width of the blade at the broadest point, exclusive of the hook, is 12 cm., while the width of the blade and hook combined is 14 cm. It has been found advisable to reduce the size of the handle by cutting and filing down the wood and iron where the knife is used by women and children, as their hands are small. In many cases native workmen accustomed to the use of "machetes," or "bolos" at first insist upon using such knives instead of this. The knife illustrated in Fig. 10, however, was specially designed to exactly meet the requirements of cane harvesting, after numerous experiments with all types of knives, including light and heavy ones, those with short as well as those with long blades. It has been observed that once workmen become accustomed to this knife they invariably prefer it to any other type.

METHOD OF CUTTING CANE

Each workman is given a separate row for which he alone is responsible. Using the hook on the top of the cane knife, he lifts up a stalk of the cane from the ground, in case it has fallen, and draws it within reach of his left hand as he does with straight cane. This he holds firmly while striking a glancing blow downward with the back of the knife to remove the leaves. The same operation is conducted on the opposite side, leaving a stalk clean of leaves. The knife is then turned and the upper portion of the stalk is struck with the blade, which removes the top. Another blow is delivered at a point from 20 to 25 cm. below the first, depending upon the condition of the cane, which removes the point and leaves standing only that part of the cane suitable for milling purposes. This is then struck with the end of the blade at a point as close as possible to the surface of the ground, indeed, rather below than above. One well directed blow should be sufficient to sever the cane from the stump. The points are then thrown in one pile while the canes are placed in another. The exact method followed of cutting the cane varies with the individual workmen and with prevailing conditions, but in general it is as mentioned above.

PRECAUTIONS IN CANE HARVESTING

There are a number of precautions which must be exercised in order to do the work properly and avoid duplication of effort. Care must be exercised that the cane is topped at the proper place. If it is cut too high the central bud will grow out when the point is planted, which would result in a very weak stool of cane. In consequence such points must later be cut to the proper length before planting, thus duplicating this part of the work. On the other hand, if the cane is topped too low there will be an unnecessary loss of valuable cane which would have been suitable for milling.

As can be judged from the explanation on cutting the cane, there should be practically no stumps left visible in the field. The lower portion of the cane is the oldest and hence the most mature of the entire stalk, so that any of this material left on the field is an unnecessary loss to the plantation. Where a ratoon crop is sought, the stool is left in better shape by this low cutting for the future crop. It is an erroneous idea that the buds on the lower portion of the cane must be left for the development of stalks in the ratoon crop. Cane matures in approximately one year and when this stage is reached the life history of the plant above ground is completed. The future crop develops from the eyes or buds on the rhizomes or underground stems of the old plant. It is evident, then, that the more completely the old stalks are removed the less opportunity there will be for fungus growth and the lodgment of insects in this decomposing cellular tissues and the less will this material be a hindrance to the work of off-barring and cultivation.

TRANSPORTATION OF THE CANE

Cane deteriorates rapidly when exposed to heat and moisture. At first this deterioration is noticed in the cut ends but in time it spreads through the entire stalk and the rapidity of the change is determined by the class of cane, weather conditions and various other factors. It is therefore evident that to recover the maximum amount of sucrose it is capable of yielding, the cane should be conveyed to the factory as soon as possible after being cut.

The modern system of transporting cane to the factory is to run a permanent railway system through the main sugar lands and lay temporary tracks in the various fields. These are taken up and transferred to other fields as the harvesting progresses. In some cases wagons or carts are used to haul the cane to the main railroad or to the mill, in case the cane is located near the mill. There are various types of cars used on the temporary tracks but the one illustrated in Fig. 15, holding approximately two tons, has given the most satisfactory results under general conditions. Where this is arranged with chains or slings unloading is facilitated and much time is saved.

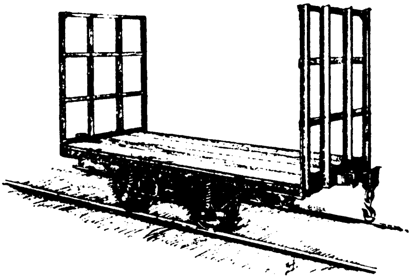


FIG. 15. Two-ton car used on light rails

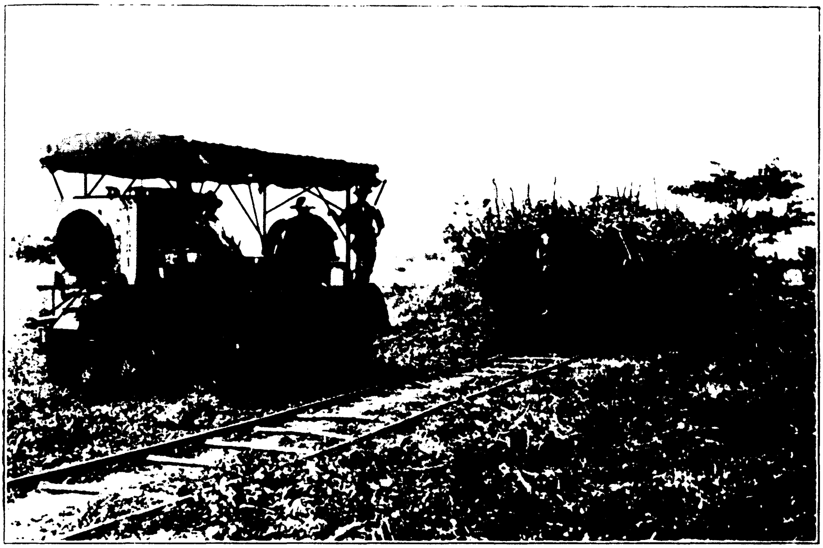
In case standard gauge tracks are employed on the permanent lines, large cars carrying approximately twenty tons of cane are employed. The cane in this case is placed lengthwise of the cars and these are run alongside and parallel with the main carrier, where the cane is readily unloaded by means of a suitable mechanical device.

(*a*) Crude and inefficient method of transporting sugar cane by using a bamboo sled drawn by a carabao

(*b*) Transporting cane by two-wheeled carabao cart. This is a slow and expensive method of transporting cane a long distance

(*a*) Transporting cane by means of a light tramway and small cars propelled by man power

(*b*) Transporting cane by means of light tramway. The small iron cars are drawn by carabao power



(*a*) Transporting cane over a medium light railway. The five-ton cars are drawn by a tractor which runs alongside of railroad

(*b*) Modern method of transporting cane by using heavy railway and locomotors

PART II

SUGAR MANUFACTURE

INTRODUCTION

The system of handling the cane and extracting the juice is in general principles the same, regardless of the class of sugar that is later manufactured. The cane from the cars and carts is weighed and the proper deduction is made for the trash included with the cane when it comes to the factory. The factor for use in making these deductions is determined by weighing the cane from a number of cars or carts, after which it is carefully cleaned of the trash and again weighed.

$$\frac{\text{Weight of clean cane}}{\text{Weight of crude cane}} \cdot \frac{100}{1} = \text{Factor}$$

It is not necessary to separate this material from the cane intended for milling, unless there is such a large amount present as to absorb the juice from the cane or produce impurities during the process of crushing.

But a proper deduction is made from the crude cane, in order that future calculations may be based on the true weight of that coming into the factory. Where cane is purchased from outside plantations, it is still more important that the true weight of clean cane entering the factory be known. Care should also be exercised to see that the cane brought to the factory was properly topped when harvested, otherwise this material, which is unsuitable for milling, should be deducted from the weight of the cane as well. The upper portion of sugar cane is always immature, no matter what is the condition of the lower portion. In consequence it contains less sucrose and yields a large quantity of impurities during crushing. These consist in part of gum, pectin bodies and albuminous substances which are "molassegenic" in their nature, hence they make the crystallization of the sucrose more difficult as well as retard the work of the pan. It is sometimes necessary to leave the cane at the factory for a time to await milling. This can be done without the loss of much sucrose in the cooler climates but in tropical countries deterioration of the sucrose begins soon after the cane is cut, due to the action of enzymes and ferments. These cause the sucrose to be split up into its component parts—dextrose and levulose—which are later reduced to acids or one of the intermediate products. When cane containing these substances is milled, a reduced yield in sugar results, while the factory operations are made more difficult and expensive, due to the introduction of juices of lower purities. It is therefore imperative that the milling be done as soon as possible after the cane is harvested.

MILLING THE CANE

The crushing plants used for this work in the smaller factories consist of three plain rolls, while in others there is in addition a crusher consisting of two deeply corrugated rolls. In the larger plants of the Islands there is a massive crusher and from two to four sets of three rolls each subjected to hydraulic pressure. Of late years the shredder has come into use either to replace or to precede the crusher for preparing the cane for the high pressure of the mills. In the large factories cane carriers are the rule. A carrier is best placed on a level with the ground in order to facilitate the unloading of the cane. It is covered with a roof in order to protect the machinery from rains as well as to furnish a more suitable place for unloading during adverse weather conditions. The cane is transferred from the cars by means of an unloading device which places it directly on the carrier.

Even in the smaller factories there should be cane carriers provided to conduct the cane to the mill, since this apparatus makes unnecessary the employment of numerous laborers.

It is important to have the cane arrive at the mill at a uniform rate in order to prevent overloading and underloading the mill, which would cause a reduction in cane milled as well as reduced extraction. If the carrier is uniformly loaded at all times, the proper feeding of the cane to the crusher .will be largely determined by the rate of speed at which the cane carrier travels. Usually this should be approximately 75 per cent of the speed of the mill. The carrier may be evenly loaded at all times by maintaining a proper movement of the cars being emptied and replaced by full ones, and by the proper manipulation of the cane feeder. The cane after passing the knives and crusher, or the shredder, is passed through the first set of rolls. The hydraulic pressure applied over the top roll varies greatly with the different factories, but on the average it will range from 100 to 300 tons. Where a multiple crushing plant is employed consisting of three or four units, the partly crushed cane from the first unit is treated with maceration water, which may consist either of pure water or of the residual juice from the last rolls. After both the second and third units, the partly crushed cane is treated with water only, in order to assist in the removal of the greatest possible amount of sucrose, or, in other words, render a high "extraction." The quantity of maceration water ordinarily employed ranges from eighteen to thirty-five per cent, calculated on the normal juice.

The juice from the various units is conducted through the main juice canal to the large juice pump and during this operation it is strained through a copper or brass sieve to remove the fine particles of bagasse called "cush-cush."

The bagasse resulting from the last rolls of a four-unit crushing plant will contain approximately 4 per cent of sucrose, 48 per cent moisture, and 45 per cent fiber. It is then considered "exhausted" of the sucrose that may be extracted readily and is conducted by a long carrier to the furnaces where it is employed to generate steam.

Since the heating quality of bagasse is largely determined by the quantity of moisture, being highest in indirect ratio to reduced percentage of moisture, it is important to obtain as dry a bagasse as possible. The following table shows the approximate relative heating capacity of bagasse with different percentages of moisture.

Net heat value of bagasse with varying moisture content

Per cent moisture	Approximate net heat value in b. t. u. per pound.
42	4,323
44	4,131
46	3,938
48	3,746
50	3,554
52	3,362
54	3,179
56	2,977
60	2,599

STEAM GENERATION

Boilers employed to generate steam in sugar factories in the Philippines are mainly of the fire tube type; but there are a number of plants equipped with water tube boilers of the Babcock and Wilcox type. Where the furnaces are properly designed and skillfully operated and the factory likewise is properly designed and equipped, the bagasse from the cane will constitute all the fuel that is required to operate a factory making 96 degree sugar.

JUICE MEASUREMENT

The mixed juice, after passing over a copper screen to remove the small particles of bagasse, is sent to the weighing station or measuring tanks as the case may be. Here the weight of the juice is carefully determined and reported on a form sheet like the model shown on page 123. It is then started on its course through the various stations of the factory.

CLARIFICATION

The purpose of this station is to effect the removal of various impurities contained in the juice in order to improve it for the subsequent work of concentration and crystallization. The impurities contained in raw cane juice are mainly of an organic nature and include such bodies as albuminous substances, glucose, gums, coloring matter and various others. These substances cause the solution to be somewhat viscous; hence they interfere with crystallization as well as give a dark color to the resulting sugar. It is, therefore, important to perform the work of clarification as thoroughly as possible, even though 96 degree sugar is being made. Where a high grade of sugar or plantation white crystals are manufactured, this work of clarification is still more important, for here it affects both the yield and the quality of the product. The kind of reagents to apply and the best manner of applying them, as well as the proper time of their application, constitute important work for the laboratory and clarification foreman.

REAGENTS EMPLOYED

There have been numerous reagents recommended from time to time for the clarification of cane juices but only the various forms of lime, sulphur, phosphoric acid and carbon dioxide have come into general use in the manufacture of plantation white sugars. Each of these serves a special purpose within its province of either precipitating or bleaching the impurities which are responsible for the yellow color of sugars.

Lime.—This is one of the most common as well as the most effective reagents employed in the clarification of cane juices. It is produced by heating high grade lime rock (calcium carborare) to a temperature of 700° C or higher, thereby decomposing the rock into its two component parts, according to the following formula:

$$\begin{gathered} \mathrm{Ca\,CO_3} \text{ (limestone) presence of high temperature} = \\ \mathrm{CaO} \text{ (calcium oxide)} + \mathrm{CO_2} \text{ (carbon dioxide)} \end{gathered}$$

A violent chemical action is set up when moisture comes in contact with the calcium oxide or quicklime sometimes called live lime. This results in a marked rise in temperature and produces a solution that is extremely alkaline. On account of this characteristic, it is not safe to apply crude lime to cane juices and so it is the general method to dissolve the lime in water and make a thick white solution known as milk of lime.

The following formula expresses the chemical reaction involved in slaking the lime for the milk of lime used in clarification work.

$$\text{Ca O (calcium oxide)} + H_2O \text{ (water)} = \text{Ca (OH)2 (calcium hydroxide)}$$

Like all bases this compound has a great affinity for acids and consequently its first action in the clarification of juices is to neutralize the acids present. It then coagulates albumins and albuminoids, which form a part of the impurities and throws down insoluble salts of sulphates, carbonates and phosphates, and of the bases iron and aluminum. These act as mechanical precipitants, assisting in bringing down other impurities such as the colloids. Many of the compounds of calcium are practically insoluble in cold cane juices, and may be readily removed by filtration or settled, and the supernatant liquor drawn off. In the application of lime, as well as of certain other reagents, much care must be taken to add the proper amount. If too little is used, there will be poor clarification and precipitating of the impurities, while if too much is used so that alkalinity is reached there will be a darkening of the compounds in the juice when heated to a high temperature caused by the decomposition of the reducing sugars by the calcium. These dark-colored compounds are very difficult of removal by whatever method is subsequently followed in the refining of such sugars. If the juice is limed to one or two cubic centimeters acidity against an N/28 alkali solution, using phenolphthalein as an indicator, there will be little or no danger of this darkening.

Phosphoric acid.—It is sometimes advisable to apply a form of phosphoric acid as a precipitating reagent to remove the excess of lime used in the previous operation as well as some other impurities. This may be used in various forms, depending upon the individual desire of the operator and the condition of the juice being treated etc.

The compounds most commonly found on the market may consist of one of the following, or some combination of them:

$H_3 PO_4$ (Orthophosphoric acid)
$CaH_4(PO_4)2$ (mono-calcium phosphate)
$Ca_2H_2(PO_4)2$ (di calcium phosphate)
Na_2HPO_4 (sodium phosphate)

The sodium phosphate has very little acidity, and the main purpose of its use is based on the principle that the sodium is readily given up for any soluble calcium that may be present. This forms the insoluble calcium phosphate, which is easily removed as a precipitate or filtered off.

Besides these forms of phosphorus, various compounds may be found on the market, under trade names, which have as their base the above acid. "Clariphos" is one of these compounds, which has found extensive use in many of the Lousiana factories.

Another is known as "Phospho-gelose." It is a combination of di-calcium phosphate $Ca_2H_2(PO_4)_2$ and infusorial silica. It is a patented preparation and is made by the absorption of phosphoric acid by a powdery compound known as "kieselguhr." After the absorption, the compound is heated to expel the water, and then resaturated. This work is repeated several times until the finished product, which is very hydroscopic, contains about 25 per cent of phosphoric acid.

Kieselguhr.—This is a fine, light powder containing a high percentage of silica. It is used purely for its mechanical effect in forming particles upon which the light impurities may be collected and thus be more readily carried to the bottom of the defecators. This material often prolongs the workings of the filter presses by collecting the gummy material which would otherwise gather on the filter cloths. Kieselguhr came into use in the beet sugar industry of Europe many years ago, and is extensively used now for the same purpose in the United States.

Sulphur dioxide.—Where a better grade of sugar than 96° test is desired, it is often advisable to subject the juice and sometimes the syrup to further treatment, one reason for which is to increase the acidity so that a larger amount of lime may be added to effect the clarification. In addition to this effect the sulphur acts to some extent directly as a clarifying agent, by precipitating some of the impurities. It also acts as a bleaching agent by extracting the oxygen from the impurities, and lastly it acts as a disinfectant. It is formed by burning crude sulphur in a stove made for that purpose. The chemical reaction involved in this operation is expressed in the following equation:

$$S\ \text{(sulphur)} + O\ \text{(oxygen)}\ \text{heat} = SO_2\ \text{(sulphur dioxide)}$$

Sometimes bombs filled with liquid sulphur dioxide are purchased for this purpose. These are inconvenient to use in sugar factories, and this method is ordinarily more expensive than the usual one of burning the sulphur and producing the gas directly at the factory.

Sulphur dioxide is a heavy gas which is very readily absorbed in water, and at a temperature of zero C., nearly 80 per cent by volume of the gas will be taken up. At 40° C., only about 18 per cent by volume of the gas will be absorbed. It may readily be seen that the percentage of gas absorbed by the juice when saturated will be determined by the temperature.

The following equation expresses the absorption of sulphur dioxide in water at ordinary temperature:

SO_2 (sulphur dioxide) + H_2O (water at low temperature = H_2SO_3 (sulphurous acid)

SO_2 (sulphur dioxide) + O (oxygen) + H_2O (water at low temperature) = H_2SO_4 (sulphuric acid)

This last named acid is very corrosive and so powerful an inverting agent that it has the property of rapidly destroying sucrose even at low temperature.

In the burning of sulphur it is well that as thorough a combustion as possible be obtained, else it will form a deposit in the tubes leading from the burners and choke them, thus retard-

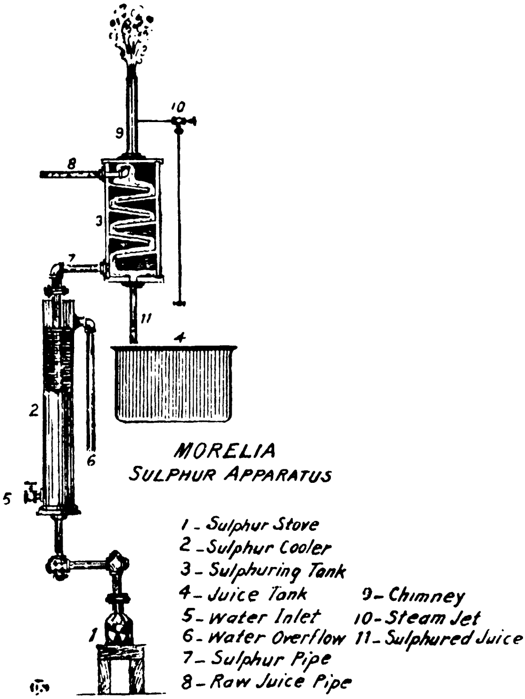


FIG. 16. Sulphur burner

ing the process. The fumes from a well-regulated sulphur furnace should contain from 15 to 16 per cent sulphurous acid. The maximum theoretical percentage obtainable is about 21 per cent of the acid.

Fig. 16 illustrates a simple stove used for burning the sulphur in small factories. Sulphur dioxide gas resulting from burning the sulphur is cooled and passed through the juices either by means of perforated pipes in the tanks or by a sulphur 'tower" fitted with shelves. In the larger and more improved factories the air to the furnace is dehydrated by mean of calcium oxide, while the sulphur gases from the furnace are passed through a filter containing pieces of coke to purify them, after which they are cooled and passed into the juice.

Carbon dioxide.—In recent years carbon dioxide gas has found a very useful application in the cane sugar factories where a good grade of plantation sugar is produced.

Java factories have been foremost in elaborating a system, through their eminent technologists, so that today one may find the bulk of the sugars they turn out from certain factories of a very satisfactory grade and color. The method they use requires a great deal of skill and attention to result satisfactorily. It is patterned after the process used in beet-sugar factories, with some distinct modifications, which make it applicable to juices containing glucose, as is always the case with cane juices.

The object of applying any clarifying material is to effect a rise in purity, and it is always especially desirable to remove the substance added, since this itself would tend to act as an impurity and thus give a lower coefficient, if not properly eliminated. When the lime has been added previously, it will be partly removed as the original precipitate and any free lime or compound which can be easily decomposed will combine with carbon dioxide, forming calcium carbonate or limestone. This is quite insoluble and may be very easily filtered off.

$$Ca\,(OH)_2 \text{ (calcium hydroxide)} + CO_2 \text{ (carbon dioxide)} = CaCO_3 \text{ (calcium carbonate} + H_2O \text{ (water)}$$

Whether single or double carbonation is used, the same general methods are employed, and results are expressed by the same chemical equation.

The carbon dioxide may be recovered from the kilns during the burning of lime, as is commonly done in the beet sugar industy, or it may be purchased in the form of liquid CO_2, in heavy iron containers. It is also feasible to use flue gases for this purpose, where there is good combustion and the percentage of carbon dioxide is high or otherwise properly treated to remove the excess of impurities present.

Hydrosulphites.—There are preparations of great bleaching power found on the market under various trade names. One of these, widely used in the United States, in both the beet and cane sugar industries, is known as "Blankit." This is sodium hydrosulphite with the chemical formula $Na_2S_2O_4$. It has a much greater bleaching and reducing action than sulphurous acid, and oxidizes very readily in combination with moisture, forming a sulphate. On this account it is well to purchase the reagent in small parcels for use in a climate such as that of the Philippines. The above substance, which is a white powder, dissolves very easily in water, forming an alkaline liquid, but this point is sometimes hard to distinguish on account of hydrogen atoms liberated.

There is a bleaching preparation made in France called "Redo" which is simply calcium hydrosulphite (CaS_2O_4). This is used in the sugar industry to some extent, but is claimed by many that the results obtained are not so good as those from the sodium compound and that it deteriorates more easily. In fact good results from the use of this reagent are obtained only when there is an excess of lime present in the juice. Hydrosulphites, unlike sulphurous acid, will bleach equally as well in an alkaline or a neutral medium as in an acid medium. There is, therefore less danger from loss of sugar by inversion when they are used, while the permanency of their effect is about the same. In any case where juices have been bleached by sulphites, the result may be considered as but temporary, since upon exposure to air and light the product assumes a darker color. Hydrosulphites should, therefore, be introduced as late in the process as possible. Where the material in the vacuum pan is to be bleached, it is well to introduce this reagent just before striking grain, thus furnishing a bright, clean material which will serve as a film over the nucleus of sucrose in the grain. The manufactures of this product state that the amount of the material used with the dry sugar should be in the ratio of 1 to 10,000. In the writer's experience, two or even three times this amount will usually be required to give maximum results.

The most suitable chemical to be used in clarification will depend absolutely upon individual conditions, which may be ascertained only by experimentation. As stated before, since the materials to be treated are so variable, each operator will be required to judge this to a great extent from the condition of his own product.

In this Islands, where a very low grade of open kettle sugar which sells very cheaply is still made, attempts are often made to bleach it and effect recrystallization in order to make a centrifugal sugar. While ordinary clarifying agents help to a great extent, if the melted sugars are very dark from caramel and the decomposition products of calcium glucosate, these reagents cannot be expected to give a light-colored juice. They may improve conditions somewhat, it is true, but the system at present recommended for use in such cases is to employ bone-char filters.

Bluing.—When "boneblack" or one of the specially prepared vegetable carbons is employed in the production of plantation clarified sugars, and sometimes of refinery crystals made from low grade sugars, there is a thin film of molasses surrounding each sugar crystal, which has a yellowish tint. It is this film which gives rise to the different grades of white sugars, when color test only is considered. Since this yelowish tinge will give way to a lighter color when neutralized with the proper shade of blue, it is a very common practice to use some form of bluing, usually that known as "ultramarine" for this purpose.

The action of this reagent is only mechanical and great care must be exercised that the proper quantity is used. This must be determined by experimenting with different amounts of the reagent, since the density of the yellowish tint is different in each case.

The place of application will also depend very much upon conditions. Some operators apply the substance in the pan just at the graining point. Again others use a quantity both at the pan and in the last charge of water at the centrifugals. In any case, a good grade only of the reagent should be used. This must be thoroughly dissolved in clear water, condensed steam being preferred, and passed through cloth or felt filters in order to remove any lumps, as these would tend to produce uneven bluing, or bluish streaks.

Animal charcoal or boneblack.—This material is made from the bones of animals, by burning them in a kiln built for that purpose. The object of this burning is to remove the easily combustible organic matter and leave the remaining carbon and mineral substances in a porous condition, so that it may be crushed into particles of the proper size. It is not desirable to have a great amount of char dust present, since this retards the passage of the liquors through the filters and impairs the efficiency of the work as well.

Bone char, being very porous, absorbs a great volume of gases among which is oxygen, and it is ordinarily presumed that its bleaching power may be attributed to this fact.

FILTRATION

Where low grade sugar is being manufactured for refinery purposes, it is unnecessary to filter all the juice and the syrup since the sugar will be dissolved later and subjected to very thorough filtration before it is made into the finished product. Another reason why this is not ordinarily done is that many of the impurities found in cane juices are colloidal in their nature and do not yield readily to filtration through cloth, hence a more effective means of removing these bodies is ordinarily found in the bone-char filters.

The material termed "mud" which settles to the bottom of the subsiders contains in addition to these light organic impurities a quantity of various inorganic compounds of calcium phosphorus and other elements which were used in clarification to effect the precipitation of the lighter organic compounds. This material may be filtered with less difficulty than the light impurities contained in the juice and since the percentage of impurities contained in the settlings is so high as to make this material unsuitable for the manufacture of even low grade sugar without special treatment, cloth filtration is resorted to here. There are various styles of filtering medium and the majority of these give good results when employed in the special work for which they were disigned. There is no station about a sugar factory where bacterial infection is so prevalent as in the filter station, due to the fact that the impurities of the factory are contained in the material handled at this place. The organic non-sugars as well as the invert sugar readily suffer deterioration from enzymes and ferments a short time after their removal from the cane and the longer they are kept the greater will be the danger of deterioration. By the time these impurities reach the filter station sufficient time will have elapsed to permit them to decompose readily and once the action of the micro-organisms is started the sucrose portion will suffer as well, hence it is necessary to exercise every possible precaution to keep down bacterial infection. After discharging each press, as much as possible of the cake and water should be cleared away and at the close of each day the presses, including all plates and other auxiliary parts, should be thoroughly cleaned. Lime should be used freely on the station presses, conveyors, cars and floors from time to time. This extra cleaning is especially important at the end of the run or week. The cloths should be washed soon after being used. If for any reason this work is delayed, even for a short time, they should be sprinkled with milk of lime.

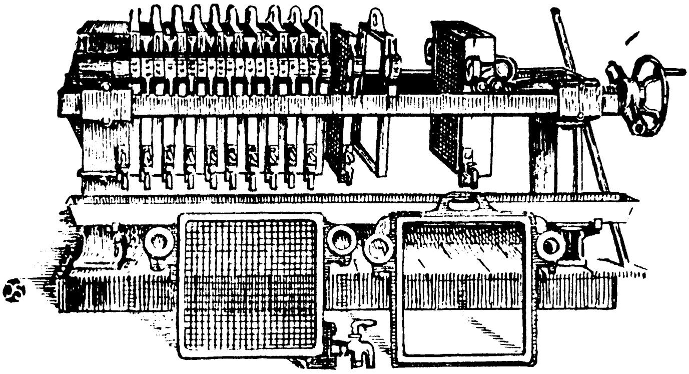


Fig. 17. Filter press

The successful operation of filtration work in the sugar factory depends upon three things; namely, the selection of the type of apparatus especially suited to the particular work, the arrangement of the apparatus, and the proper handling thereof.

At present the plate type of press on the order of that illustrated in Fig. 17 is universally employed in the Philippines. These presses vary somewhat in design, depending upon the factory from which they were made, but the same general principle is employed in all and when properly handled they give satisfactory results. The filter station should be located on the second floor of the factory or at least three meters (10 ft.) from the ground floor. This permits the discharge of the press cakes directly into the cars or carts by means of gravity, thus economizing in labor.

The storage tank for the settlings from the subsiders should be placed approximately 5 meters (16 feet) above the presses. This tank should contain two discharge pipes, the one leading to the presses and the other to the filter press pump. There should be two sets of troughs at the presses, the one to receive the filtered cane juice for use at the evaporations and the other for the wash water which is sent to the storage tank and used in the first laxivation.

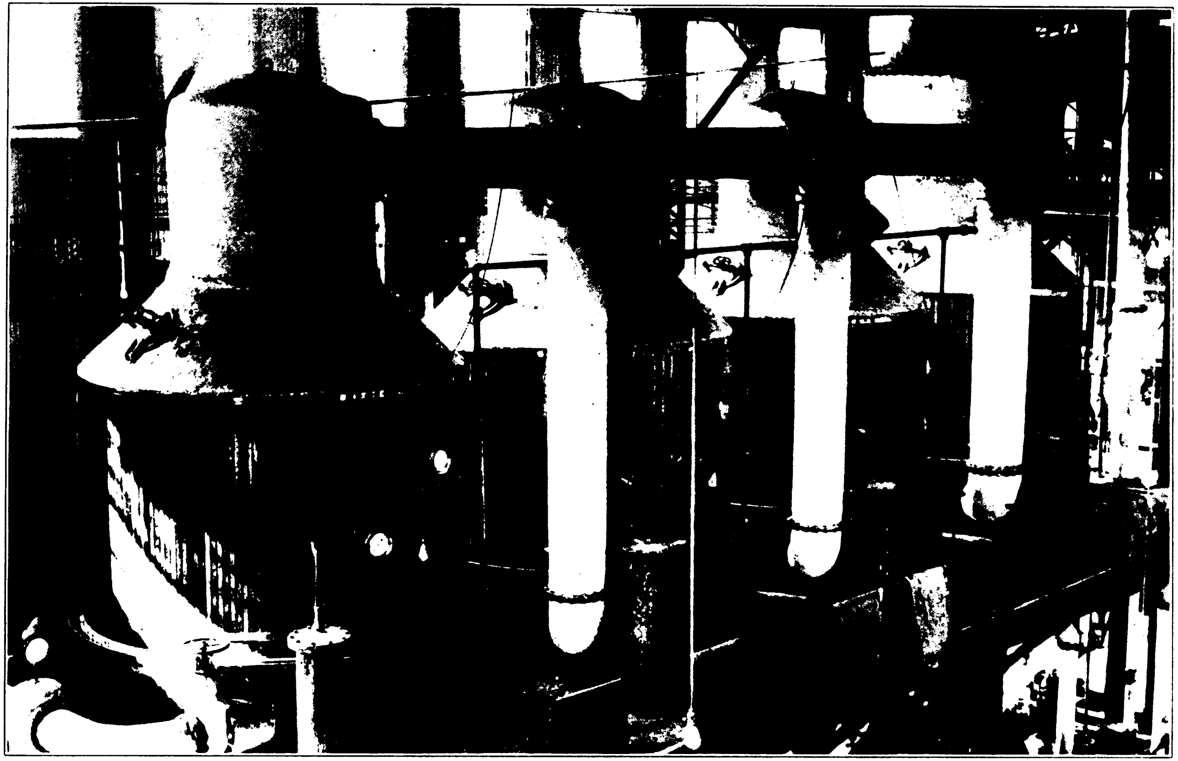


PLATE XVI. Quadruple effect evaporating plant

PLATE XV. Open train evaporating plant

Method of operating.—The presses are prepared for filtration by having the frames containing the canvas cloths and the empty frames placed alternately one against the other until the required number are set in position. Care must be exercised that all joints are made perfectly tight. The filter press is then securely closed by means of lever pressure. The discharge cocks are opened one-fourth of the way, after which the material to be filtered is turned in through the pipe from the main storage tank. The discharge cocks should be watched and opened more or partly closed as the case demands. The length of time during which gravity pressure is employed depends upon the size of the presses used and condition of the juice being filtered. When filtration becomes slow, the valve from the gravity main is closed and pressure from the pump is employed, the juice in this case passing directly from the tank to the pump. A pressure of approximately 25 pounds per square inch is maintained until the presses are completely filled with mud and filtration becomes slow. The discharge faucets of the presses are opened for about five minutes and either sweet water from previous laxivation or pure water is forced through the mains for about twenty minutes; the faucets are then closed almost completely and the pressure gradually increased to 35 or 40 pounds. The water resulting from this washing may be mixed with the filter press juice in case it was previously used as wash or put into a separate tank for use as the first wash in the future. After the water is used as a wash a second time, it is mixed with the filtered juice and sent to the evaporator supply tank. When this washing is finished, the pump is stopped and steam is forced through the intake pipes at a pressure of about 100 or slightly higher. This is continued for approximately 10 minutes, the discharge valves of the presses being kept wide open in the meantime. The wash from this operation is sent to the storage tank and used in the first wash the next time.

The work of washing the press cake is gauged largely by chemical analysis. If too little water is employed there will be an unnecessary loss of sucrose at this station, while if the washing is prolonged too far excessive amounts of impurities will be introduced into the filtered juice and an unnecessary dilution will result which will necessitate the expenditure of extra heat in the evaporation of this water. It is seldom economical to wash the filter press cake to a lower sucrose content than three per cent, under conditions here.

EVAPORATORS

After the juice has passed through the clarification process, it is ready for concentration. In modern practice this is always done under reduced pressure or in a partial vacuum. Since the point at which a liquid will boil is determined by the vapor pressure above, it being greater in inverse ratio to the pressure, any reduction in the pressure will cause the solution to boil at a lower temperature.

The table on page 170 shows the temperature at which water will boil under various pressure of different degrees of vacuum.

Effects.—The inventors of evaporators have taken advantage of this principle in the design of these apparatuses and have evolved a system of evaporators known as "effects," whereby the exhaust steam from the engines, formerly a waste product, effects the removal of practically the entire quantity of the water necessary to reduce the juice to syrup. They are constructed of various units and the effect of the initial steam is noted in them all. There are various styles of effects on the market, each with its own peculiar merits.

Vertical effects.—This style of effect is commonly employed in the factories of the Philippines. They are so named because of the fact that the main body of the evaporator as well as the tubes are placed in a vertical position. There are a number of makes embodying the general design of this type.

Horizontal effects.—This style of evaporator is so named from the fact that the main body as well as the tubes are placed in a horizontal position. There are numerous makes of evaporators embodying this feature.

In general construction effects contain a juice space situated over the heating surface and above this is a large vapor space. In the case of the vertical effects the heating space usually consists of a calandria made up of vertical tubes set in iron or copper plates. Steam envelopes the tubes containing the boiling juice. Leading from the first effect is a large steam pipe which extends from the top of the first unit to the calandria or heating space of the second. This, as well as the third unit in the case of a quadruple effect, is constructed identically like the first, with respect to the vapor tube leading to the succeeding unit. The vapor tube leading from the last number terminates in a large condenser where the vapors are condensed by the water which constantly pours in during the operation. By the condensation of these vapors a vacuum is created in that unit. By reason of this vacuum the juice boils at a lower tem-

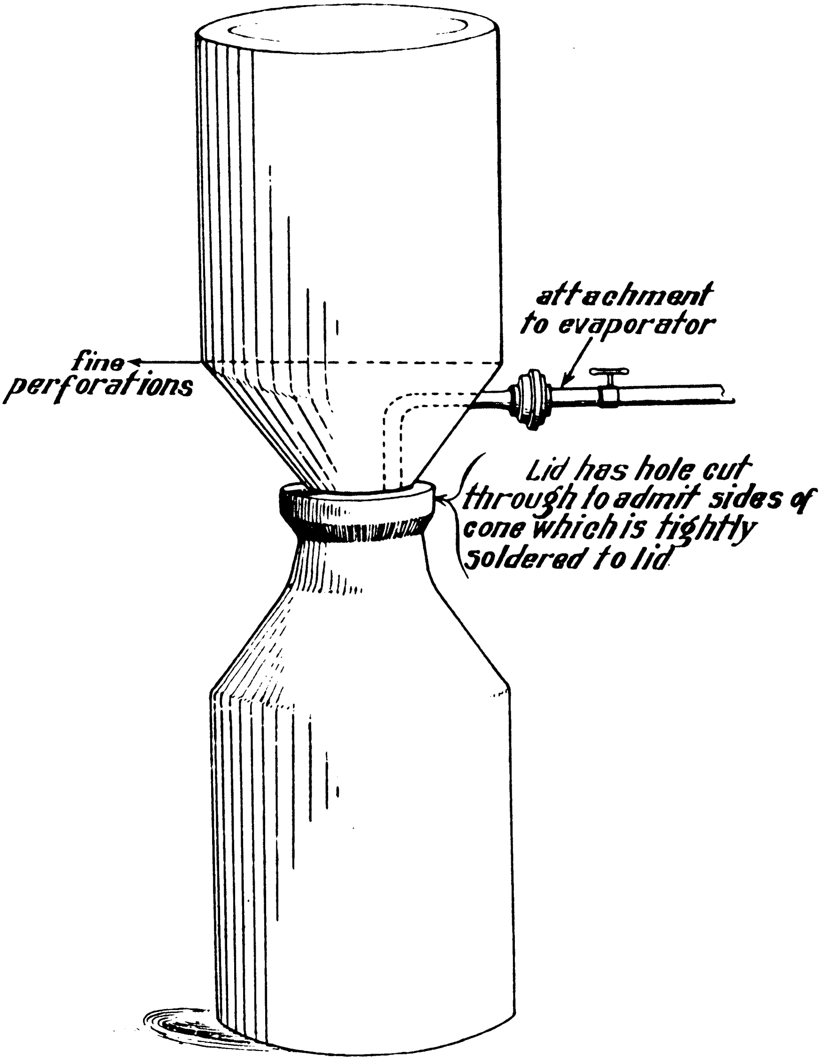

attachment to evaporator
fine perforations
Lid has hole cut through to admit sides of cone which is tightly soldered to lid

FIG. 18. Walker's molasses separator

perature than would be possible otherwise. This cooler mass causes the steam from the preceding unit to be relieved of its heat and thus condensed; this in turn causes a partial vacuum to be formed in that unit. Likewise this vacuum causes the juice in unit three to boil at a lower temperature, with the result that the vapor from number two effect is condensed, making a partial vacuum in that unit. The same system is followed in the case of unit one, but here only a very slight vacuum if indeed any at all results. The calandria or steam space of each unit is connected with a steam trap which permits the water formed from the condensed steam to pass off.

Manipulation of effects.—The general principle involved in the manipulation of effects is that of letting the juice flow into the first unit from the juice supply tank, which is placed at a slightly higher level than the effect itself, until the proper level is reached. This height must be determined for each particular class of evaporator, but as a rule it is preferable to boil the juice at as low a level as possible, thus reducing the effect of the "hydrostatic head" or liquor pressure from above.

The vacuum pump is started, and exhaust steam from the engine is turned into the calandria of the first unit. The temperature of this steam will be somewhere between 100 and 105 degrees C. and consequently the juice in the first unit will boil at atmospheric pressure, or 100° C. The valves in the pipe line connecting the several units of the effects are then opened and a limited amount of the juice in the first unit is conducted to the calandria of the second and the condensed vapor is removed at the steam trap. A vacuum of 8–15 inches of mercury is maintained in the main body, consequently the juice will boil at from 92 to 82 degrees C. The juice from this unit is conducted to the third effect, where a vacuum of 16–22 inches of mercury results. The liquor in this then boils at something near 75° C. From this unit the liquor passes to the fourth, the vapor space of which is connected directly to the condenser. The vacuum in this unit will be near 28 inches of mercury; consequently the liquor will boil at a temperature somewhat above 38° C.

The degree of density to which syrup is boiled is determined by the amount of exhaust steam available as well as by the desires of the sugar boiler who will later handle the syrup. In general it is more profitable to concentrate to as high a density as possible in these apparatuses in order to economize in live steam in the work following in the vacuum pan; consequently the density of the syrup usually ranges between 50° and 60° Brix. When this evaporation is completed, the syrup is sent to storage tanks to await further concentration and finally crystallization in the vacuum pan.

THE VACUUM PAN

The apparatus employed in boiling sugar to grain is known as a vacuum pan. This is a large cylindrical vessel terminating in a dome from which extends a large vapor tube leading to the condenser and vacuum pump. This tube is provided with an apparatus known as a "catch-all," designed to collect any entrained syrup that may pass over with the vapors, and thus prevent its loss.

The bottom of the vacuum pan is either rounded or cone shaped and at the extreme lower portion there is a large gate valve from which the finished massecuite is removed. Vacuum pans vary in diameter from six to twenty feet, depending upon the amount of sugar being boiled.

They are constructed in two general designs, the coil type and calandria. In the former the steam used for heating is introduced through large copper coils connecting with a steam trap, while in the latter case it enters the calandria, which consists of tubes set vertically in large plates. The former offers the advantage of being easily discharged but the latter that of providing a larger heating surface in a given area.

Vacuum pans are provided with a delicate vacuum gauge which consists either of an ordinary mercury atmospheric barometer, or of one containing a mechanical device giving the same general results. They are also provided with a thermometer, steam gauge on the pipe line, a proof stick by which samples of the boiling liquor are removed and near the top or at the side with a manhole through which the workmen may enter to make repairs and to clean the apparatus. Where grain is used as "seed", this manhole serves a useful purpose for introducing the seed-sugar.

Sugar boiling.—The final process of concentration or boiling the sugar consists of removing more water from the already heavy syrup until the sugar is forced out of solution by means of crystallization. This work requires the operator's closest attention, especially from the time a state of supersaturation is reached until the crystals have grown to the desired size and the resulting molasses is properly reduced of its sucrose.

This condition is accomplished by carefully guarding the temperature while at the same time watching the concentration of the solution. The boiling temperature of a solution is determined by the air pressure above as well as the density of the solution. The theory of crystallizing sucrose out of solution implies that evaporation or the removal of water is continued until a state of saturation is reached; or it might be said that it is a state of equilibrium with reference to the sucrose therein contained. The amount of sugar dissolved in one part of water in this condition has been designated by Dr. Claassen, the world's authority on sugar crystallization, as "S", and when the state of supersaturation is reached the amount of sucrose in solution is designated as "S1", and the ratio designating the supersaturation coefficient is expressed by the formula $\frac{S1}{S}$. This refers to the number of times as much sucrose that is dissolved in the supersaturated solution as compared with a saturated solution at the same temperature. This is the point that is of primary importance in boiling sugar. It must be borne in mind that this supersaturation coefficient is established independently of the temperature. The purity of the solution, however, exerts a very marked influence; consequently the work of boiling sugars differs materially with each particular grade of product. The heating surface of the vacuum pan should be so arranged that the boiling mass will be uniformly heated throughout the apparatus. The violent churning about of the mass during boiling will cause a thorough mixing of the massecuite to result, but unless the heating surface is properly arranged, there are likely to result local disturbances caused from these obstructions. The greatest evaporation takes place near the heating surface and consequently the mass at this place will be the more dense. Likewise the state of supersaturation is likely to be very much disturbed by the charging of the pan, from time to time, if this is not done very gradually and especially if the syrup inlet is not properly placed. For that reason the syrup inlet should be placed somewhat low and the syrup before entering should be heated to as high a temperature as the boiling mass.

The system which has ruled in the craft of boiling sugar has been largely empirical in its nature and only in recent years have attempts been made to employ the analytical results of the various products attained in the sugar laboratory as an aid in conducting the work. Even now it is more the exception than the general rule to find the theory of crystallization conscientiously followed out by sugar boilers. Sugar boiling is not a work which requires special ability on the part of the operator; but, as mentioned before it does require a great deal attention and constant application on the part of the operator until the steam is turned off. This is why one often finds persons of practically no educational training whatsoever who master the art in an empirical manner and obtain passable results.

The first operation in the boiling of sugar is to see that the pan is properly prepared for the work. The large valve at the bottom and the air valve of the pan must be properly closed. The vacuum pump is started and water is turned into the condenser. When sufficient air has been removed from the pan (15″ to 20″ vacuum) to permit the syrup to enter, the valve to the syrup tank is opened and the required amount of syrup is admitted to produce the necessary amount of grain for the "strike", or pan of sugar, being boiled. The valve is then closed and steam is turned into the coils or calandria as the case may be. Should it be found upon observation after concentration has gone on for some time, that not enough syrup was drawn into the pan at the start to produce the required amount of grain, the valve is again opened and a little syrup is admitted, the process being repeated from time to time until the necessary amount is present. Where a very fine grain is desired it is necessary to use a larger amount of syrup than would be required for sugar of a coarse grain. It has been explained that the state of supersaturation of the boiling solution will be different for the various purities. Where purities of the syrup range from 86 to 92, it should range from 1.2 to 1.5 for the best results. After the proper quantity of crystals or grain have been produced to give the desired size of grain in the finished sugar, more syrup is drawn into the pan, while at the same time the state of supersaturation is kept as low as possible. This will permit the grain, which is at first very fine, to gradually increase in size. During the preceding operations it requires much skill and attention to keep the grain already formed from dissolving as well as to prevent the formation of new grain.

Any grain that should happen to form after the requisite amount was produced is known as "false grain." This may be considered the *bête noir* of all sugar boilers, since the final results of their work are largely determined by its presence or absence. The false grain not only takes up some of the sucrose in the solution which should be deposited on the crystals already formed, but also offers even greater trouble by gathering over the perforations of the centrifugal screens and thus impairing the work at that station as well as causing unnecessary loss of sucrose in the molasses.

Should false grain be produced through lack of attention or because of the difficulty of working the heavy mass, the sugar boiler must put forth every effort to dispose of it. He may raise the temperature of the boiling mass by admitting more steam into the coils of the calandria, which has the effect of reducing the vacuum; and, according to the table of solubilities on page 170 this will have the effect of dissolving some of the grain. These crystals may also be dissolved by opening the syrup valve and letting in a quantity of syrup. The same results might also be attained by drawing in a small charge of water, but this necessitates the expenditure of heat to again evaporate the water.

A sample of the boiling liquor is withdrawn by the proof stick from time to time; and its viscosity is carefully guarded so that the proper state of supersaturation shall be maintained. The length of time required to boil the strike of sugar is determined by the design and condition of the vacuum pan, the purity of massecuite and the efficiency of the boiling work. Concentration is continued until the grain has reached the desired size and the massecuite is relieved of as much sucrose as may be conveniently crystallized under the prevailing conditions. This results in a molasses of a low purity. The steam line to the pan is then closed and the massecuite is discharged into the "mixture." At the same time the stirring apparatus within the mixer is set in motion and continues revolving until the last of the massecuite passes through the centrifugals.

HANDLING THE SUGAR

SEPARATION OF SUGAR FROM MOLASSES

The massecuite is passed through the centrifugals soon after leaving the pan. Ordinary workmen may be trained to handle these machines but there should be one person among them who is charged with the results of this station. The price obtained for the sugar depends upon its grade or polarization, in the case of 96° test sugars; and the grade of sugar manufactured is largely determined by the care taken at this station. When the machines are starting on a new strike, the sugar is washed with a measured quantity of water estimated to be correct for that particular massecuite. A sample of the resulting sugar is immediately sent to the laboratory, where it is polarized. The laboratory report on the sample is at once forwarded to the centrifugal station. If 96° sugar for refinery use is being made the sugar should test somewhere between 96° and 97°. If the first experiment yields a sugar testing less than 96°, it will be necessary either to spray more water on the sugar in the centrifugals or run the machines a short time longer. If, however, the sugar tests more than 97°, less water will be required. In cases where extremely high grade massecuites are employed, like those often resulting from the juices from cane grown on the old lands of the Philippines, it is sometimes unnecessary to wash the sugar if the massecuite was properly boiled and purged in the centrifugals. Where high grade plantation white sugar is manufactured directly from the cane juice, it may have a yellowish cast due to the film of brown molasses which surrounds the crystal of sucrose. This yellowish tint may be neutralized by using a small amount of bluing in the last wash.

The centrifugaling of low grade sugars does not differ materially from that of 96° test sugars except that more wash water is required to bring them to the desired polarization. Where third or last sugars from the centrifugals are being passed through the centrifugals, the resulting molasses is termed "final molasses", since it is not economical to extract more sugar from it. In this case the wash resulting after water has been sprayed on the crystals must always be separated from the molasses, in order to leave as little sucrose as possible therein. This wash is mixed with the first molasses in the production of second sugars, or in a "boil-back strike." It is sometimes desirable to separate the wash from the molasses in making the higher grades of sugar, including both 96° and plantation white.

Let it be added that attention should be given the screens of the centrifugals, especially if they have been used for some time, to see that they have no large holes through which the sugar would escape into the final molasses. The wooden paddles used in discharging the centrifugals often break such holes. Only short-handled paddles should be used for this work but if the workmen are permitted to do so, they will invariably use paddles with longer handles, since less work is required with such paddles.

The holes in centrifugal screens, if not too large, may be patched by placing pieces of old screens on the reverse side and attaching same with a hard solder.

DRYING THE SUGAR

The sugar from the centrifugals is sent to the drying room, in case high grade or plantation white sugar is made and sometimes with 96° sugar. There it is passed through an apparatus known as a "drier", which consists of a hollow cylinder constructed of sheet iron. These driers vary in dimensions but are usually about two meters in diameter and five or six meters long. They are provided with little shelf-like projections on the inner side which catch the sugar during the revolution of the cylinder on its axis and let it sift down, meanwhile a current of hot air is forced through by a fan placed at one end. The granulator is tilted with one end higher than the other, thus causing the sugar to move downward gradually during the revolution of the cylinder. A radiator containing steam pipes serves to heat the air that enters the drier and the efficiency of the drying work depends upon the proper heating of the air entering the outfit.

BAGGING AND WEIGHING THE SUGAR

When the sugar has been dried, it is conveyed to the sacking room, where it is sacked and weighed after being thoroughly cooled. Sugars that are bagged while hot are quite likely to cake in the bag, which impairs their quality for direct consumption and makes them difficult to handle.

The scales used for weighing the sugar should be tested from time to time to insure their proper adjustment. A difference in weight of but a fraction of a kilo on each bag will make an appreciable variance from the true weight in the output of even a single day. It may readily be observed that the error during a campaign of five or six months would be something of much importance.

STORING THE SUGAR

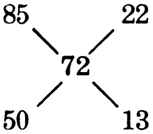
The warehouse for storing the sugar should be constructed with special reference to proper ventilation in order to keep the sugar as dry as possible during the rainy weather. The various ventilators and windows should be provided with storm doors, which are to be kept closed during rainy days when there is danger of the rain beating in. These will also serve to retain the dry air that is already present in the room and exclude the damp air during a markedly rainy spell if they are closed when the rains begin. They should be again opened when the weather permits and kept open whenever practicable.

The floor of the sugar room should be constructed sufficiently high to permit proper ventilation from underneath, if the ground is at all damp where the warehouse is situated; or else it should be constructed of a very heavy layer of concrete that is practically impervious to water.

MOLASSES

The molasses from the first sugar may be disposed of in various ways. If the purity is high enough it may be used to boil a "straight second." The main objection to this method, however, is that a sugar with a rather low polarization may result unless the purity is quite high or much water is used in washing the sugar at the centrifugals. Where 96° test sugar is desired and the second sugar polarizes but a little below standard, it may be mixed with a proper amount of first sugar that is too high, so that the desired average polarization of 96.5° will be obtained.

Another system of handling the first molasses is to make what is known as a "boil-back" by producing the grain from the straight syrup and finishing with the first molasses. In this case it is necessary to have an analysis of both the syrup and molasses and the tanks should be provided with gauges so that the required amount of material from each may be readily withdrawn. The necessary purity of the massecuite to give maximum results under prevailing conditions is first decided upon and from the analysis of each, the syrup and molasses, the required percentage is determined. The following scheme of Cobenze forms a simple means of determining the amount of each, syrup and molasses, required to give a massecuite of a certain desired purity when the purity coefficient of each is known.



Two liquids have purity coefficients of 85 and 50 per cent respectively. The problem is to determine how much of each must be used to obtain a liquid with a purity coefficient of 72. In the diagram as above, place the higher purity number in the left hand upper corner, the lower purity number in the left hand lower corner, and the desired number in the middle. Working crosswise, deduct the lower from the higher figures and place the result in the extension of the diagonal lines; that is 85, the purity of the syrup, minus 72, the purity of the resulting mixture gives 13; and 72, the purity of the mixture, less 50, the purity of the molasses, equals 22. The resulting upper figure, 22, now indicates the amount (by weight or volume) of the liquid with the higher purity to be used and 13, the lower resulting figure, that of the lower purity.

A "boil-back" strike is one that contains molasses which is boiled again in a mixture of syrup and molasses. This is handled in both the pan and centrifugals in a similar manner to the straight strike. The molasses resulting from this will be sufficiently reduced of its sucrose content to make further crystallization difficult and slow. In consequence the wash is separated from the molasses at the centrifugals and used with the syrup, while the molasses in "boiled blank" to string proof and put in either crystallizers or tanks.

Discard molasses.—The molasses resulting from the third boiling is unsuitable for further crystallization and is no longer serviceable in the sugar factory. In consequence it is employed in one of several methods described later, depending upon conditions.

CRYSTALLIZERS

These apparatuses are so named from the work which they perform. They are large tanks of various shapes, each containing a stirring apparatus and a discharge gate. Each crystallizer should be of a size to hold exactly one boiling from the pan. The low grade molasses is boiled to sufficient density for the sucrose to crystallize with the greatest rapidity under prevailing conditions. The exact point to which this is boiled differs with each class of product so that no set rule can be given. The sugar boiler determines the "end point" through experience in the boiling of low grade products by observing their behavior when drawn into a string or rolled into a ball and pressed flat under water. It is not even necessary for sugar crystals to appear before the boiling mass leaves the pan, though they are quite often present.

After the massecuite is boiled to sufficient density it is dropped into a crystallizer and the stirring apparatus is made to revolve slowly. The length of time required for crystallization in these apparatuses will be determined by the purity of the material and the way it was boiled. Generally, however, from three to six days will be required to give a molasses of a low purity. The Walker molasses separator illustrated in Fig. 18 serves a very useful purpose in removing the molasses from the crystals before the analysis of the samples.

This apparatus consists of an ordinary glass fruit jar, preferably of a quart capacity. The zinc lid has a hole cut 2½ inches in diameter, through which the funnel portion passes, where it is soldered tightly. The upper portion of the funnel is approximately 5½ inches in diameter and is soldered to the upper can of the same diameter and approximate height. This upper can contains a copper or brass bottom with fine perforations, which is soldered in place at the junction of the funnel and upper can. A piece of ½-inch pipe bent at right angles enters the side of the cone and extends down slightly below the union of the lid and the funnel. The other end of this pipe terminates in an ordinary union coupling which is operated by hand. This coupling is arranged for attachment to another pipe of the same diameter which is securely attached to the side of the last number of the effect or to the vacuum pan. This tube extends about 6 inches from the evaporator and contains a valve which is operated only when the apparatus is in place.

To operate it the lid should be screwed tightly to the lower jar. In the upper receptacle is placed the desired quantity of massecuite, usually from one to two pints. The apparatus is attached to the evaporator at the union of the ½-inch pipe, care being taken that the union is air tight. The valve located on that portion of the pipe near the evaporator is opened, which causes the air in the jar to be drawn into the evaporator and creates a vacuum in the jar, whereby the molasses from the massecuite above flows at once into the jar.

CRYSTALLIZING TANKS

Where there are no crystallizers with stirring apparatus available, ordinary tanks may be employed for this purpose; but in this case more time must be given to the work. The partly exhausted molasses near the crystals is not removed and replaced by rich molasses, as would be the case where the heavy mass is properly agitated in a crystallizer by a stirring apparatus.

The writer has obtained final molasses with an apparent purity of 29% in factories here in the Philippines but such results require extremely careful boiling of the massecuite and much time for crystallization. The sugar obtained from third massecuite under ordinary conditions will not test up to 96° unless much washing is done in the centrifugals, in which a great deal of sucrose is washed away with the molasses adhering to the crystals. It is therefore better to remelt the low grade sugar in the clarified juice and send it along to the evaporators. This procedure entails no extra heat in the evaporation and very little work. Another method is to employ this sugar to reduce the polarization of first sugar by mixing the proper percentage of each. Still another method is to employ this sugar as "seed" upon which the sugar in the second molasses is boiled. And the fourth method is to sell the sugar as "seconds." This is about the most unsatisfactory method of all, ordinarily, since a very great reduction in the price is usually made by sugar buyers for sugars testing much below 96°. Well regulated plantation factories are able to make all of their sugar into 96° test by one of these above mentioned methods.

SCIENTIFIC CONTROL IN SUGAR MANUFACTURE

In modern practice the manufacture and refining of sugar is conducted under strictly scientific control. This requires that an exact account be kept of the sucrose entering the factory in the form of crude material—cane; and of that leaving in the form of the finished product—sugar; and of the by-products bagasse, filter-press cake and molasses, as well as that of the material in process at the various stations throughout the factory.

This work requires that all weights and measurements be accurately taken and that the various products throughout the factory be properly sampled and carefully analyzed. In order that results be properly applied by those responsible for the operation of the factory, the various reports are submitted to the laboratory by the operators in charge of the different stations throughout the factory. A compilation of these data constitutes what is known as the daily and weekly report.

Field report

Number or name of field......................................

Date of analysis	Variety of cane	Date of planting	Canes per stool	Water per cane	Yield of cane per hectare

Composition of juice			Per cent of juice extracted	Cane		Tons cane per ton sugar	Sugar per hectare	Remarks
Brix	Sucrose	Purity		Sucrose	Fiber			

Report of cane weighed

Factory.. Campaign..
Crop day .... Date..

Cane weighed today	
Cane weighed previously	
Cane weighed to date	
Cane weighed but unmilled (cane in yard)	
Cane milled today	
Cane milled previously	
Cane milled to date	

....

Cane weigher

Mill report

Factory
Crop day

Campaign
Date

Began grinding	Time employed Hours	Time employed Mins.	Stopped grinding	Time lost Hours	Time lost Mins.	Cause of stop
Total						

Engineer

Juice measurement

Factory
Crop day

Campaign
Date

Total	Liters of juice	Specific gravity	Temperature	Weight of dilute juice	Normal juice Weight	Normal juice Per cent of cane
To day						
Previous						
To date						

Foreman

In case a weighing apparatus is provided, the taking of measurement, specific gravity and temperature of the juice is omitted. Where provision is not made for this, and the above observations are made, the weight of the dilute juice, percentage of maceration water, the weight of normal juice and the percentage of juice extracted are inserted by the laboratory assistants.

Lime station report

Factory
Crop day

Campaign
Date

Total	Density of lime solution	Quantity	Acidity of juice	Time required for settling	Remarks
To day					
Previous					
To date					

Reported by

Filter station report

Factory.................................... Campaign....................................
Crop day.................................... Date....................................

[6 a. m. to 6 p. m.]

No. of Press	Started	Finished	Remarks.	No. of Press	Started	Closed	Remarks

Number of cloths used....................................
Weight of press cake produced....................................
Per cent sucrose in press cake....................................
Weight sucrose in press cake previously reported....................................
Weight sucrose in press cake to date....................................

Filter Station Foreman....................................

Crystallizer record

Factory.................................... Campaign....................................
Crop day.................................... Date....................................

Pan No.	Crystallizer No.	Time filled	Purity of mass	Time out	Polarized sugar	Purity molasses	Sugar boiler	Remarks

....

Crystallizer Foreman.

Pan report

Factory.................................... Campaign....................................
Crop day.................................... Date....................................

Pan				Grade	Start	Stopped	Time boiled	Syrup		Molasses			Purity		Drop
A	B	C	D					Hec.	Pur.	Hec.	Pur.	Crys.	Mass.	Mol.	

Commercial sugar produced

Factory.................................... Campaign....................................
Crop day.................................... Date....................................

			Polarization	Remarks

Weight of sugar for day previously....................................
Total to date....................................

Reported by....................................

Note.—On the opposite side of the same sheet the sugar made during the night shift is reported in the same manner as above. This report includes the time from 6 p. m. to 6 a. m.

Molasses report

Factory .... **Campaign**
Crop day .... **Date**

Date	**Produced**			**Purity**	**Remarks**
	Hectoliters	**Specific gravity**	**Temperature**		
Total					
Previously					
To date					

Reported by ....

Weekly report stock on hand

Factory .... **Campaign** ....
Crop day .... **Week ending**

Material	**Tank No.**	**Centimeters from top**	**Cubic meter or hectoliter**	**Material**	**Tank No.**	**Centimeters from top**
Juice				**First massecuite**		
Total						
Syrup				**Second massecuite**		
Total						
First molasses				**Second molasses**		
Total						

From a compilation of the reports submitted by the various station foremen and the analytical results of the various products, the chemist's accounting system is operated. In the chemist's record book the various results are kept. A brief from the convenient system devised by Mr. Irving Morse and used in the sugar factories of Louisiana is given herewith including some additions.

Dilute or mixed juice

Factory .... **Campaign** ....
Crop day .... **Week ending**

Date	**Solids**	**Sucrose**	**Purity**	**Glucose**	**Non-sugar**	**Ratio**	**Juice**	**Sucrose**	**Glucose**
For week									
Previous									
To date									

Normal juice

Factory..............................

Crop day..............................

Campaign..............................

Week ending..............................

Date	Solids	Sucrose	Purity	Glucose	Non-sugar	Ratio	Juice	Sucrose
							Kilos	*Kilos*
For week								
Previous								
To date								

Clarified juice

Factory..............................

Crop day..............................

Campaign..............................

Week ending..............................

Date	Solids	Sucrose	Purity	Glucose	Non-sugar	Ratio	Sucrose	Glucose
							Kilos	*Kilos*
For week								
Previous								
To date								

Results of clarification

Factory..............................

Crop day..............................

Campaign..............................

Week ending..............................

Date	Ratios.				Purity			
	Dilute juice	Clarified	Filtered	Syrup	Dilute	Clarified juice	Filtered juice	Syrup
For week								
Previous								
To date								

Filtered juice

Factory..............................

Crop day..............................

Campaign..............................

Week ending..............................

Date	Solids	Sucrose	Purity	Glucose	Non-sugar	Ratio	Juice	Sucrose
							Kilos	*Kilos*
For week								
Previous								
To date								

Bagasse report

Factory..............................

Crop day..............................

Campaign..............................

Week ending..............................

Date	Sucrose	Moisture	Fiber	Bagasse	Sucrose
	Per cent	*Per cent*	*Per cent*	*Kilos*	*Kilos*
For week					
Previous					
To date					

Mill extraction

Factory.................................... **Campaign**....................................

Crop day.................................... **Week ending**....................................

Date	Cane	Dilute juice	Saturation water	Normal juice	Juice Extracted	Sucrose Extracted
					Per cent	*Per cent*
For week						
Previous						
To date						

Sucrose account

Factory.................................... **Campaign**....................................

Crop day.................................... **Week ending**....................................

Date	Sucrose			Per cent sucrose on sucrose			
	Cane	Juice	Bagasse	A Juice	B Bagasse	C Sugar	D Molasses
	Kilos	*Kilos*	*Kilos*				
For week							
Previous							
To date							

Filter station report

Factory.................................... **Campaign**....................................

Crop day.................................... **Week ending**....................................

Date	No. of presses	Press factor	Sucrose	Sucrose
			Per cent	*Pounds*
For week				
Previous				
To date				

Pan report

Factory.................................... **Campaign**....................................

Crop day.................................... **Week ending**....................................

Date	Strike No.	Massecuite			Pur. Mol	Drop	Sugar Pol.
		Brix	Sucrose	Purity			
For week							
Previous							
To date							

Molasses report

Factory.......... Campaign..........
Crop day.......... Week ending

Date	Solids	Sucrose	Purity	Weight of molasses	Weight of sucrose
For week					
Previous					
To date					

Crystallizer report

Factory.......... Campaign..........
Crop day.......... Week ending

Date	Strike No.	Solids	Sucrose	Purity	No. of crystallizer	Cubic meter	Kilos	Weight sucrose	Weight available sucrose
For week									
Previous									
To date									

Final Molasses

Factory.......... Campaign..........
Crop day.......... Week ending

Date	Solids	Sucrose	Purity	Weight of molasses	Weight of sucrose
For week					
Previous					
To date					

Commercial sugar

Factory.......... Campaign..........
Crop day.......... Week ending

Date	Strike No.	Serial No.	Weight	Polarized	Weight of sucrose	Result
For week						
Previous						
To date						

The station reports are submitted to the laboratory, which constitutes the accounting department of the factory. These reports, in conjunction with the analytical results of the various products, enable the chemist to prepare a balance sheet of the factory operations. A brief of this constitutes the report rendered to the manager at the close of each day, and at the close of the week or run a more complete report is made according to the following:

Daily factory report

Factory
Crop day

Campaign
Date

	To-day	To date
Hours of grinding		
Cane ground		
Mill extraction, juice in cane		
Dilution per cent		
Sucrose extracted, per cent sucrose in cane		
Purity normal juice		
Purity clarified juice		
Purity syrup		
Purity of final molasses		
Hectoliters final molasses		
Per cent sucrose in bagasses		
Per cent sucrose in filter press cake		
Kilos sugar manufactured		
Polarization of sugar		
Moisture in sugar		

Remarks

Chief Chemist.

Weekly report

Factory
Crop day

Campaign
Week ending

Entered and manufactured kilos cane
Entered sucrose in the cane—sucrose present

Sugar produced	Kilos	Polarized

Sugar in process (estimated)

Factory .... **Campaign**

Crop day .... **Week ending** ....

LOSSES.

	Kilos	Per cent sucrose	Tons sucrose	Per 100 cane	Per 100 sucrose
Bagasse					
Press cake					
Molasses					
Undetermined					
Total losses					
Recovery					
Sucrose entering mill					
Sucrose lost at mill					
Sucrose entering boiling house					
Sucrose lost in boiling house					
Days of grinding					
Weight of cane ground to date					
Weight of cane ground per day					
Weight of sugar produced to date					
Weight of sugar produced per day					
Tons of cane per ton of sugar					
Weight of waste molasses to date					
Waste molasses per thousand ton of sugar					

Final molasses produced to date ...., kilos ...., sucrose ....

....

Manager.

LABORATORY INSTRUCTIONS

Accurate work in sampling the products throughout the factory and in the execution of the various analytical determinations in the sugar laboratory will result only from extreme care and constant attention on the part of the analyst. Unless such work is properly done the results will be misleading and therefore detrimental rather than beneficial when employed in directing factory operations.

It is essential in the first place that high-grade instruments be provided for the laboratory and that this equipment be properly adjusted and protected in every possible manner to keep each instrument in proper condition. Among the various important instruments found in the sugar laboratory are included the polariscope or polarimeter, refractometer, analytical balance, gravity spindles, etc. These are all very delicate instruments which require special handling and unless they receive it satisfactory laboratory results will be unattainable.

Too much stress cannot be placed upon the necessity for keeping the laboratory clean and each and every piece of apparatus in perfect condition. The analyst who is careless in this respect is usually careless about his analytical work and computation of results as well; and results which do not represent accuracy in every detail are useless. It should be remembered that only a very minute dilution of the product to be analyzed will cause, in many cases, appreciable inaccuracies in the results of the analysis and therefore the necessity for observing the above precautions is apparent.

Among the various analytical determinations in the sugar factory there are two which are of prime importance in the control of the various manufacturing operations; that of total solids and sucrose. From these two determinations the purity coefficient of sugar solution is determined and any change in the purity of the product as it passes from one stage of manufacture to another is indicative of the efficiency of the work done. It is obvious that analyses of this nature should be conducted with the utmost care, since so much stress is placed upon them in the control of the operations about the factory.

DETERMINATION OF TOTAL SOLIDS

The total solids or total dry matter in sugar products may be determined by various methods; namely, by drying, by the refractometer, specific gravity spindles, pyknometer, and Westphal balance, as well as by numerous other methods which have not come into general use. So long as the work is conducted with care, it matters little which method is employed in control work. It is necessary, however, to select a method which will permit the work to be done with dispatch in order that the results may be available to the factory manager during the time the material is in process to guide him in his work.

For this reason gravity spindles and the refractometer are usually preferred for sugar factory control.

GRAVITY METHOD

There are various systems of determining total solids by using the principles of gravity. One of the earliest of these systems to come into general use was that of the Baumé hydrometer. There are various other types of hydrometers in use for this work, all embodying the same general principles. These instruments consist of hollow glass or metal spindles with graduations on their stems for taking the relative specific gravity of liquids. They are so weighted as to float in an upright position when placed in a liquid.

One of the earliest of these systems to come into general use was the "Baumé." The scale in this case had no direct bearing on the specific gravity of sugar solutions and hence the readings were only relative terms when applied to sugar house products.

The scale on the spindle originally prepared by Balling was found to be somewhat inaccurate and was afterwards revised by Brix. The spindles universally employed today are of this design and on that account they are known as "Brix spindles" and the determinations as "Brix" or "total solids." The scales on these instruments are so arranged as to indicate directly the percentage of total solids present in sugar solutions when the reading is taken at the standard temperature to which the instrument was calibrated. The normal working temperature varies with the different sugar countries and for that reason instruments properly calibrated for the special working conditions should be provided. The original Brix spindles were calibrated at 17½° C, and this is the standard still quite generally employed in subtropical sugar countries. A new standard of

20° C was later adopted by the International Congress of Applied Chemistry. In tropical countries the normal working temperature is still higher, consequently the instruments are standardized at 27½° C or 28° C. On page 167 may be found tables to be used in making the corrections for the different temperature variance.

In the purchase of Brix spindles it is essential that high-grade instruments be procured. The stem of these instruments should be at least 18 centimeters long and the range of each instrument should be but 10 degrees. In order to make the reading comparatively accurate the scale divisions should be divided into ten parts.

While it is not absolutely essential, it is often desirable to have each instrument fitted with a properly standardized thermometer in order to facilitate the work of obtaining both gravity and temperature. Otherwise a thermometer must be specially provided for this work.

All high-grade instruments for determining total solids are calibrated before leaving the factory. It is not safe, however, to assume that either the graduation marks on the spindles or those on the thermometers are absolutely correct until the chemist himself has checked them carefully. The simplest method of testing these instruments is to carefully make up a number of solutions using standard sucrose of various concentrations corresponding to the scale of the hydrometer. It is not necessary to test each scale division in this manner but at least four such tests for each spindle should be made. These may indicate the two extremes as well as two intermediate points. At the same time the scale on each instrument is verified the thermometer may be checked against a standard thermometer.

METHOD OF USING BRIX SPINDLES

The cylinders used in connection with Brix spindles for determining total solids may be constructed either of copper or glass material the latter being preferred, since the condition of the solution and escape of the air bubbles may be better observed from these cylinders.

Those for general use should be sufficiently large in diameter to permit the spindles to move freely about in them, but it is well to have at hand a number of cylinders of a smaller diameter for samples when there happens to be only a limited amount of the specimen available.

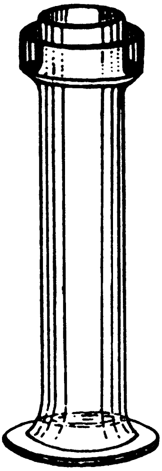


FIG. 19. Cylinder for use in determining Brix of solutions

Cylinders containing a large outer portion or circular trough at the top like that illustrated in Fig. 19 are preferred although not absolutely necessary, since these permit the gravity determinations to be made on clean tables without the juice spilling over when the spindles are inserted. Where ordinary cylinders are used, there should be a special table provided for this work and after each set of samples is finished the table should be washed to assist in keeping it free from bacterial infection. This table should be constructed with a zinc or lead bottom and have the edges raised two or three centimeters so the water will not slop over when it is being washed. The samples arriving from the various stations of the factory each have a card bearing a number as well as the name of the product. This card may be placed in front of the cylinder or even underneath it after a composite sample of the product is obtained. The remainder of the solution from the sample pail should be emptied into a container and transferred to the juice tank and the pail should be thoroughly washed and dried for use in collecting other samples. The drying of these pails is not absolutely necessary for all of the sugar-house products; they might be rinsed with a portion of the solution to be analyzed and thus no dilution from the moisture in them would result. Nevertheless, it is a good practice to dry every specimen bucket, since this not only prevents unnecessary dilution of the samples but also assists in keeping down bacterial infection. The dry cylinders having been placed in a row, the samples of juice should be poured through a brass strainer (See Fig. 20) into the cylinders until they over-

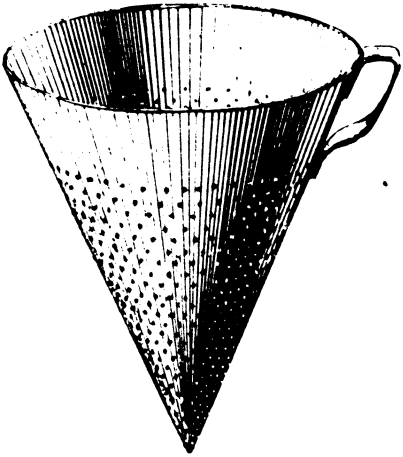


FIG. 20. Strainer for cane juices of either brass or copper

flow. The cylinders are then left to stand a few minutes until the air bubbles escape and the Brix spindle is carefully inserted after the stem has been wiped with a dry cloth. The stem of the spindle is read at the level of the liquid. Fig 21 indicates the level of the solution as well as the curved surface of the liquid near the stem of the spindle. The height of this meniscus varies with the viscosity of each particular solution and consequently the reading of the spindle would differ with each solution were the above precautions not taken. The reading is recorded as the uncorrected Brix or total solids. At the same time the reading of the temperature is taken. Separate thermometers may be used for this purpose, or those contained in high grade spindles, after they have been carefully standardized. If a thermometer registers a temperature higher than that at which the instrument is calibrated, it indicates that the liquid occupies a slightly greater space than it would at the normal temperature and consequently the number in the table at the intersecting lines of temperature and degree Brix found in the appropriate table on page 167 should be added to the uncorrected Brix. If the working temperature is lower than that to which the instrument is calibrated the proper factor must be subtracted from the Brix reading. This gives the corrected Brix or total solids. The above result should not be confused with the true total solids obtained by the drying method, which will be explained later.

It is well to dilute all sugar-factory products for analysis, except the sugars themselves, to approximately the same den-

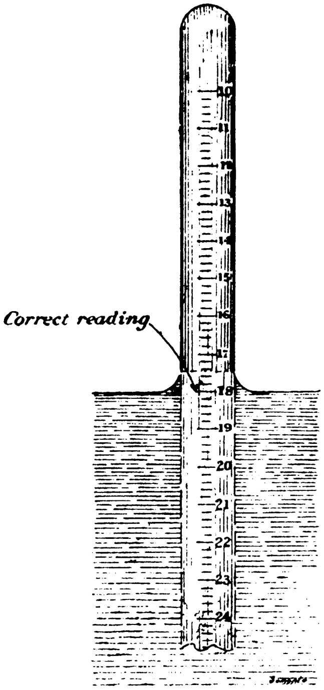


FIG. 21. Correct reading line for Brixing solutions

sity, in order to have the laboratory results more nearly uniform. These dilutions are best made in carefully tared copper or aluminum cans of approximately 600 cubic centimeters capacity. There should also be carefully prepared copper counterpoise weights for the various cans and a special weight for each dilution as well.

The weights for the dilutions are prepared as follows:

No. 5	100 grams	for ⅕ dilution
No. 6	83.33 grams	for ⅙ dilution
No. 7	71.43 grams	for ⅐ dilution
No. 8	62.50 grams	for ⅛ dilution
No. 10	50 grams	for ⅒ dilution

METHOD OF MAKING THE DILUTION

The tared can is placed on one pan of the balance with the counterpoise weight on the other. The weight of the can should be checked from time to time with the counterpoise, as well as the weight for each sample for dilution. The corresponding weight giving the required dilution is put on the beam with the counterpoise weight and the required amount of the well mixed sample is placed in the dilution can. The special weight is then removed and an ordinary 500 gram weight put in its place. The required amount of clean rain water is then added, after which the mixture is removed from the balance and prepared for analysis. All analytical determinations of the diluted samples should be multiplied by the appropriate factor to reduce them to the original solution. For example, if molasses has been diluted to $\frac{1}{6}$ of the original sample, all analytical results should be multiplied by 6.

TOTAL SOLIDS BY THE REFRACTOMETER

There are various style of the refractometer on the market but the two most generally used in sugar factory determinations are known as the dipping (see Fig. 22) and the Abbé (see Fig. 22). These instruments depend upon the principle that the refractive indices of various substances are constant for each particular material. Determinations of total solids by the refractometer must be made at the temperature to which the instrument was calibrated or temperature corrections made accordingly. These instruments form by far the most convenient method of determining total solids. It is not necessary to dilute

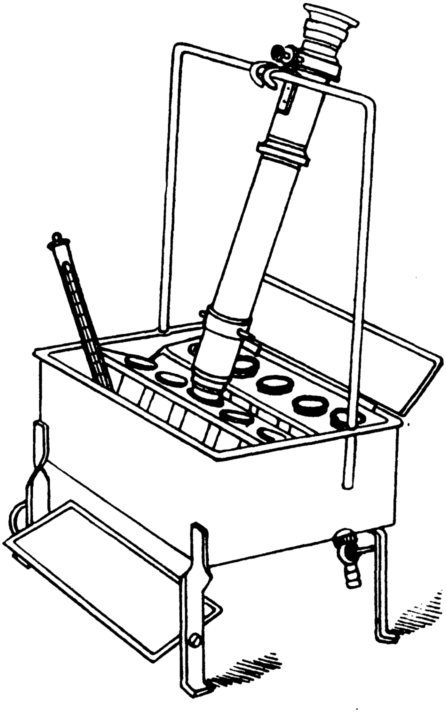


FIG. 22. Dipping refractometer

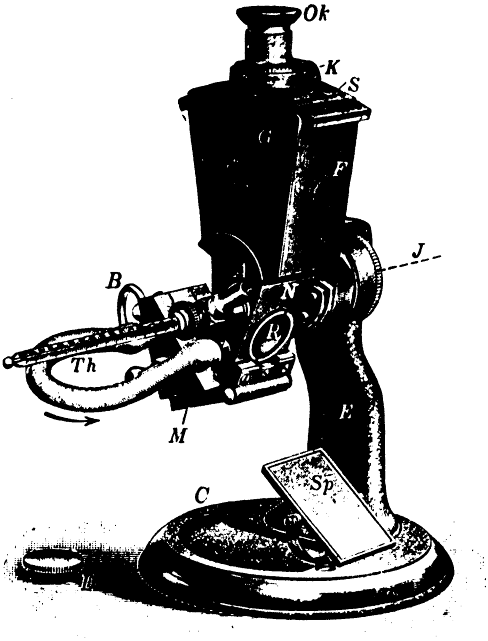


FIG. 23. Sugar refractometer

the heavy solutions as required in the previous method where the refractometer is employed, except when the specimen contains sugar crystals, in which case a known amount of water must be added to make up the solution.

In determining total solids by the Abbé or new sugar refractometer, (see Fig. 23) a few drops of the well mixed sample are spread over the surface of the lower wedge, the instrument is closed and the refractive index read, while at the same time the temperature is carefully noted. It is very important that the temperature be constant during these determinations, and in order to provide for this a stream of water is passed through the instrument by means of tubes for that purpose.

TOTAL SOLIDS BY DRYING

This method is considered by many chemists to be the most nearly accurate of all the methods employed to determine true total solids. It has been the writer's experience that equally as accurate results may be obtained by using the refractometer and in addition valuable time is saved to the laboratory force, since the drying method requires the expenditure of much time and labor. A number of carefully tared shallow platinum, copper or aluminum dishes must be provided for determining total solids by the drying method. Large areas will accelerate evaporation and to provide for this a little coarse as well as some fine pumice stone is scattered evenly over the bottom of the dish. It is then heated to drive off traces of moisture, cooled in a desiccator and carefully weighed. A sufficient amount of the specimen to be analyzed to give between one and two grams of dry mater is next weighed. The drying is preferably done in a vacuum oven at a temperature between 75° C to 80° in order to prevent decomposition of the more unstable compounds. Where such an oven is not available, the ordinary hot-water oven may be used. Whichever system is employed, the sample is dried to constant weight and cooled in a desiccator. These results are known as true solids or true dry matter.

OTHER METHODS

While the pyknometer and Westphal balance as well as various other methods are available to the sugar chemist for determining specific gravity and from this total solids, they have not been generally employed and consequently mention only is made of these.

POLARISCOPE AND ACCESSORIES

The polariscope is one of the most expensive as well as the most delicate instruments found in the sugar laboratory. Its essential parts consist of lenses made from high-grade glass; prisms from Iceland spar, (a very rare calcite rock found in Iceland) ; and wedges cut from exceptionally pure and flawless pieces of quartz rock, all of which are enclosed in a rigid metallic case.

These instruments are made by experts in their line and it is very important that they be handled with extreme care in order to keep them in perfect adjustment. They must also be protected from any possible damage due to sudden jar, extreme heat and from corrosion. Many valuable instruments have been ruined by the heat from the polariscope lamps melting the special cement used in attaching the two faces of the Nicol prisms and either causing air bubbles to be formed between them or letting the prisms get out of alignment. Even a slight overheating of thse delicate parts may cause a change in the polarimetric determinations although it may not be sufficient to permanently damage the instrument. For this reason the sources of light should be given due consideration. It is essential to use a clear light which gives off a minimum amount of heat for the polariscopic observations. Where electric lights are available, frosted

Tungsten bulbs will answer very well and these lights are very convenient to use. In case the laboratory is provided with a gas plant, ordinary mantle lamps containing frosted globes will answer or similar globes may be employed with a gasoline or an alcohol lamp.

While a separate room for the polariscopic determinations offers some advantages, yet it is often convenient to have the instrument located on a table in the laboratory proper and covered with a box which may be approximately one meter long by 60 centimeters wide and 60 centimeters high. This box should be painted black inside and have a black curtain at the back to be thrown over the operator during the time he is making polariscopic readings. The front of this box should have a hole about 4 centimeters in diameter from which the end of the polariscope protrudes. This system not only shuts off outside rays of light and makes the reading of the polariscope easier on the eyes of the operator but it also protects the instrument, in a measure, against excessive heat from the lamp.

POLARISCOPE TUBES

There are various styles of polariscope tubes on the market each serving for certain specified lines of work. The normal length of these tubes is 200 millimeters. This kind is used for ordinary work but there is also included with each instrument, in addition to this, a half normal or 100-millimeter tube for use with very dark solutions and a double normal or 400-milimeter tube for use with very dilute solutions. Tubes should be selected which are made of glass, as this material is not subject to great expansion from heat nor is its length readily changed from bending, as is the case with metal tubes.

Where the ordinary polariscope tubes are employed, it is well to select those in which one end is slightly enlarged for the escape of air bubbles beyond the main portion of the tubes. See tube "*a*" in Fig. 24. This style of tube offers the disadvantage of requiring two separate sizes of washers and cover glasses. The Bates design of tube, "*b*" Fig. 24, eliminates the above difficulty while at the same time it overcomes a defect in the design of other tubes which are supported upon the edge of the caps rather than on a shoulder from the main portion of the tubes. This is an important improvement, since an unequal stress on any portion of the cover glass may make it become optically active and thus cause an appreciable error in the polariscope reading.

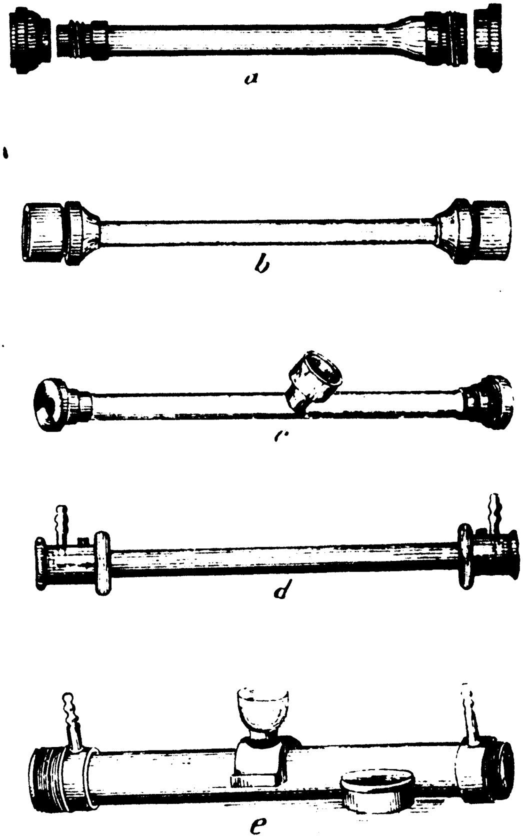


Fig. 24. Polariscope tubes.

Tubes containing an opening in the center for filling and emptying as indicated in "*c*," Fig. 24, are convenient where rapid determinations are made, as this design obviates the removal of the cap in filling. Where care is exercised in keeping the tubes clean, this style proves a great convenience in certain lines of work.

In case a number of determinations are being made of material similar in composition, such as the various products in control work, the use of the Pellét continuous tube "*d*" Fig. 24, effects a saving of both time and labor on the part of the analyst and when a sufficient amount of the sample is run through the tube before the reading is taken practically as accurate results may be obtained by this system as when the old style tube is employed.

In using the last named method the tube is left in the trough of the polariscope continually, while each new sample is run through by having the beaker containing the specimen placed below the glass tube connected with the polariscope tube by a rubber hose of the same diameter. The rubber portion contains a pinch-cock by which the flow of the liquid is controlled and when an analysis is finished the glass beaker containing the specimen just analyzed is replaced by the new specimen, the pinch-cock is released and the liquid is siphoned through the tube, while that from the previous sample is forced out through the discharge tube of the siphon.

In addition to the above-mentioned polariscope tubes, there should be provided one or more inversion tubes for use in determining sucrose by the Clergét method. These tubes are jacketed with a brass covering in order to permit a current of water to pass through the tube and thus regulate temperature during polarization. The jacketed tubes should be used for no other purpose than for making the above determinations.

It is essential that all polariscope tubes be properly cleaned and dried after each set of analyses. The cover glasses should be cleaned with very soft cloth or tissue paper to prevent them from being scratched. Only rubber washers that are quite soft should be employed, in order to prevent the cover glasses from being subjected to an unequal strain when the cap is inserted. Such a strain will often cause an appreciable difference in the polariscope readings. An error from this source may readily be detected by turning the tube in the polariscope through and reading it in different positions.

There is a slight difference in rotation between quartz used in the construction of the compensation device of the polariscope and sucrose and in making polarizations of light-colored solutions such as those from high grade sugar, it is necessary to use a light filter to compensate for this difference. These filters are made by filling a 3-millimeter tube with a 3-per cent solution of potassium bichromate and filtering the light through this medium during polarization.

In order to test the accuracy of the polarimetric scale, there should be provided two standard quartz control plates, one for checking one of the higher scale divisions and the other for one of the lower divisions. These plates are usually provided with the instrument. They should nevertheless be carefully checked against a standard sugar solution before being employed in testing the scale of the instrument.

PREPARATION OF SPECIMEN FOR POLARIZATION

In the successful execution of analytical sugar work, promptness and accuracy are two of the essentials. Unless analytical results of various sugar factory products are immediately available while the work is in progress, they are valueless in the control of the manufacturing operations. Absolute accuracy is quite often as important and in simultaneously carrying on a large series of analyses in control work it is necessary that every possible convenience be at hand to facilitate the work. It is also essential that space on the laboratory tables be so economized that the analyst will not be required to move about from place to place in carrying on the various operations.

In the preparation of specimens for polarimetric work the first operation is to obtain a clear solution for the observation tube. It is the experience of every sugar chemist that the first filtrate which passes through the filter paper after the addition of the clarifying reagent is very cloudy, due to the presence of more or less colloidal material. There are also quite often present traces of lint as wall as moisture from the filter paper. This material causes a delay in the obtaining of a clear filtrate and also reduces the degree of accuracy in the polariscopic reading. The common custom of throwing away the first portion of the filtrate is unsatisfactory, since traces of these colloidal bodies are certain to remain in the receiving glasses, however carefully the rinsing with new filtrate is done.

In order to eliminate this difficulty and at the same time provide a convenient rack which will permit a large number of

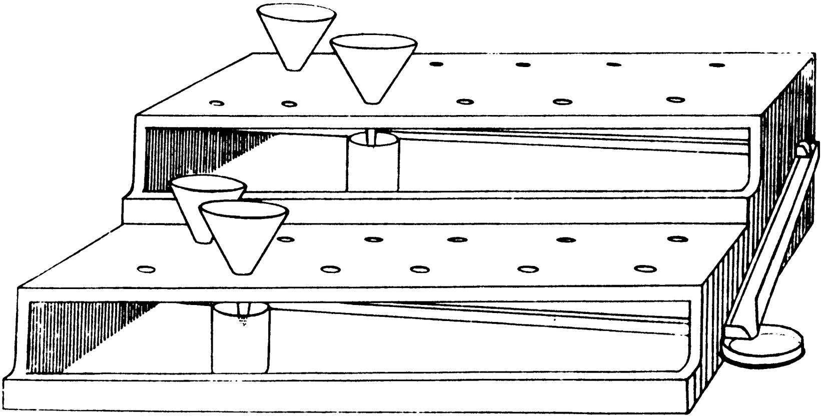


FIG. 25. Filtering rack

samples to be analyzed consecutively without any danger of confusion of samples, the writer has employed, with very satisfactory results, the filtering rack shown in Fig. 25. This apparatus offers an economy in desk space over those usually employed and there is less opportunity for confusion of samples on the part of the laboratory assistants in preparing their specimens for analysis. The apparatus consists of a double filter rack, the forepart being 60 centimeters. The distance from the front to the back of the apparatus is 60 centimeters, each compartment being 30 centimeters in width. The length of the apparatus is determined by the number of filters it is desired to accommodate at one time. An outfit for twelve samples should be approximately 75 centimeters long.

The shelf of each compartment is 24 centimeters wide and contains holes 2 centimeters in diameter, the first of these being located 7 centimeters from the side and the other 12 centimeters from the center of the previous hole.

The first row of holes is located 4 centimeters from the front edge and the second 7 centimeters from the back edge. Beneath the back row of holes in both the front and rear racks are placed small pans or troughs of galvanized iron which receive the first filtrate that passes. After the clear liquid has begun to pass through, the funnels are moved forward to the front row of holes and placed above the clean beakers to receive the filtrate for polarization.

DETERMINATION OF SUCROSE

Sucrose is always determined by the aid of the polariscope. There are numerous methods of preparing the samples and assaying the sucrose, each of which possesses special merits for certain lines of work. If the work is carefully executed, there is no material difference in the analytical results obtained by the use of the various methods in direct polarization.

The scale on polariscopes or saccharimeters is so arranged that the percentage of sucrose in the sample may be read directly if a definite amount of the sample is made up to a certain specified volume at a certain temperature, and the observation made in a tube of the specified length under certain definite conditions. In the weighing method the normal weight of the specimen consists of 26 grams when employing a modern instrument calibrated for the use of the true cubic centimeter as the measure of the diluted sample. Where the old system, or Mohr

FIG. 26. Nickel silver capsule with counterpoise and normal weights

flask, is employed the normal weight of the sample will consist of 26.048 grams.

A tared nickel silver dish or capsule, like that shown in Fig. 26, should be used in weighing out the sample. This dish should be provided with a carefully prepared counterpoise weight. The weighed sample is washed into a calibrated 100 cubic centimeters flask which has been thoroughly cleaned and dried, thus preventing the sample and wash water from adhering to the neck of the flask. The sample is thoroughly dissolved by giving the flask a circular motion, after which the solution is clarified with a minimum amount of lead subacetate to effect the precipitation of the impurities and give perfectly clear reading in the polariscope. The sample is then made up to the 100 cubic centimeter mark, thoroughly agitated and filtered. In case the specimen consists of high garde sugar, a small amount of aluminum cream will be sufficient to induce filtration and give a clear liquor; but where there are dark-colored impurities present a small quantity of the lead subacetate is necessary to effect clarification.

When the reading is made in a normal, or 200-millimeter, tube the percentage of sucrose may be read directly from the scale on the polariscope. But in case the solution is derived from dark-colored material, it is sometimes necessary to read it through a half-normal, or 100-millimeter, tube and in this case the reading must be multiplied by two. If the product being analyzed is of very low concentration, it is sometimes desirable to use the double normal, or 400-millimeter, tube and then the polariscope reading must be divided by two.

SUCROSE BY HORNE'S DRY LEAD SUBACETATE METHOD

This is one of the most convenient methods of preparing solutions for sucrose determinations and is especially suitable for control work where numerous samples of similar material are analyzed.

A convenient amount, approximately 100 cubic centimeters, of the solution is treated with the necessary quantity of dry lead subacetate to effect clarification. This is best accomplished by using small glass cylinders, which may be easily shaken by holding them mouth down against the hand. The solution is then filtered and read in a 200-millimeter tube. By reference to the table on page 178 the percentage of sucrose is determined directly where the uncorrected Brix of the solution is used in conjunction with the polariscope reading.

SUCROSE BY THE 100-110 CUBIC CENTIMETER DILUTION METHOD

Carefully calibrated flasks having long necks are employed in this method. Near the lower extremity of the necks of the flask is a mark indicating 100 cubic centimeters capacity and above this is another mark indicating a capacity of 110 cubic centimeters. The flask is filled to exatly the lower mark. After sufficient lead subacetate has been added to effect clarification, it is filled to the second mark with rain water. The solution is then throughly shaken, filtered, and read through a 200-millimeter tube. By reference to the table on page 172 the sucrose content may be obtained.

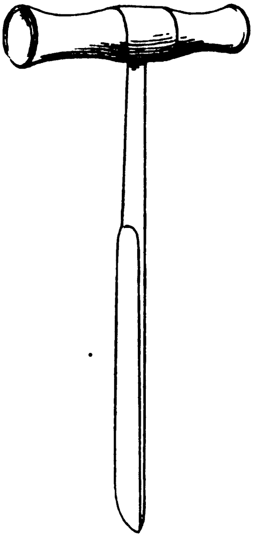


FIG. 27. Sampler for sugar and filter press mud.

SUCROSE BY SPENCER'S PIPETTE METHOD

This method was devised simultaneously by Dr. G. L. Spencer and C. A. Crampton. It requires a special pipette with a long stem bearing the necessary graduation marks as shown in Fig. 28. The pipettes usually carried in stock are calibrated for the double normal weight of 52.096 grams and may be employed

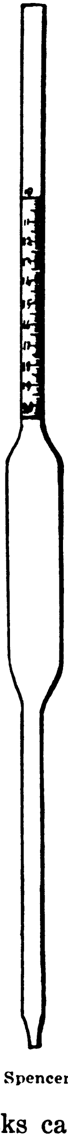


FIG. 28. Spencer's pipette

only in conjunction with flasks calibrated for the Mohr system. In determining sucrose by this method, the pipette is filed to the mark corresponding to the uncorrected Brix of the solution. This is run into a flask, clarified with lead subacetate made up to the 100 cubic centimeter mark with clean water, shaken thoroughly and filtered. The clarified solution is then read through a 200-millimeter tube and the result is divided by two.

It is obvious that this method is applicable only to solutions of a light density, such as juices. The viscosity of heavy solutions would make it difficult to fill and empty the tube. Where all the sugar-factory products are diluted to approximately the same density, as explained on page 135 this method may very readily be used for all of them except sugar.

When sucrose is determined by any of the above methods the analytical results are termed the direct polarization.

The ratio of these results to the total solids of the solution obtained by the gravity spindles gives the apparent purity.

$$\frac{\text{Sucrose by direct pol.}}{\text{Corrected Brix}} \text{ X } 100 = \text{Apparent purity}$$

CLERGÉT OR INVERSION METHOD

True sucrose is determined by the inversion, or Clergét method, as outlined in the Official Methods of Analysis, United States Bulletin No. 107, as follows:

Free 50 cubic centimeters of the filtrate obtained by the direct method from the lead which was used for clarifying the original sample. This is best accomplished by adding a minimum amount of the prepared potassium oxalate solution. Filter and place in a 100 cubic centimeter flask exactly 50 cubic centimeters of the filtrate with 25 cubic centimeters of clean, preferably distilled, water. Then add, little by little, while rotating the flask, 5 cubic centimeters of 38.8 per cent hydrochloric acid solution. After gently shaking the mixed solution by giving the flask a rotary motion, place it in a water bath with a temperature of 70° C. The temperature of the solution in the flask should reach 67° to 69° C in from two and one-half to three minutes. Maintain a temperature of as nearly 69° C as possible during seven to seven and one-half minutes, making a total time of heating of ten minutes. Remove the flask and cool the contents rapidly to 20° C and dilute to 100 cubic centimeters. Polarize this solution in a tube provided with a water jacket, passing a current of water around the tube maintain a temperature of 20° C.

The inversion may also be accomplished as follows:

To 50 cubic centimeters of the clarified solution, freed from lead, and 5 cubic centimeters of a 38.8 per cent solution of hydrocloric acid and set aside during a period of twenty-four hours at a temperature not below 20° C; or if the temperature is above 25° C, set aside for ten hours. Make up to 100 cubic centimeters at 20° C and polarize at that temperature. This reading must be multiplied by two, which gives the invert reading. In case it is necessary to work at a temperature other than 20° C, which is allowed within narrow limits, the volumes must be completed and both direct and invert polarizations must be at exactly the same temperature. The sucrose is calculated by the following formula:

$$S=\frac{100\ (P-I)}{142.66-\frac{T}{2}}$$

S = direct reading
P = invert reading
I = invert reading
T = temperature at which readings are made

OTHER DETERMINATIONS

DETERMINATION OF GLUCOSE

The volumetric method for determining glucose is sufficiently accurate for ordinary sugar-house products and this method offers the advantage of requiring little time on the part of the analyst.

The solution to be analyzed should be of such a glucose content as to require approximately 20 cubic centimeters of the prepared sample to reduce the copper in exactly 10 cubic centimeters of the copper sulphate, or 20 cubic centimeters of the mixed Fehling solution. After the percentage of glucose is determined in the prepared sample, this figure should be multiplied by the proper factor to reduce it to the percentage in the original solution.

Where the dry lead subacetate method of clarifying the juice for the sucrose determination has been employed, a portion of the filtrate may be used for the glucose analysis after sufficient sodium carbonate has been added to make the solution neutral; or, better still, after the excess of lead has been precipitated with a sufficient amount of the prepared potassium oxalate solution. After the sample has been properly made up and filtered, the burette is thoroughly rinsed with a portion and filled above the zero mark. The height of the solution is then reduced to the zero point by means of the stop-cock, in order that the small portion of the burette beyond this point shall be filled before the analysis is begun.

Measure out 20 cubic centimeters of the prepared Fehling solution, or 10 cubic centimeters each of the copper sulphate and the alkaline tartrate solutions, into a porcelain casserole; heat to the boiling point and add as nearly as possible the correct amount of the specimen from the burette; again place the casserole over the flame and boil for two minutes.

Filter off a drop of the supernatant liquor on a "spot plate" after the first portion of the filtrate has passed into the casserole, and return the small filter paper to the original solution. The spot plate is prepared for the test by having a drop or two of acetic acid and of potassium ferrocyanide placed thereon. If a red color is observed it is evident that there is still present copper in the unreduced state and consequently more of the sample from the burette must be added and the solution boiled for another two minutes. When just enough of the solution has been added so that the red color no longer appears, the copper has all been reduced and the number of cubic centimeters of juice from the burette is recorded.

The amount of glucose present may be determined by reference to the table on page 171, or it may be computed as follows:

Assuming that the Fehling solution was made up of standard strength according to the instructions given on page 158, twenty cubic centimeters of the mixed solution will require 0.05 grams of glucose for its reduction. The following calculation then gives the percentage of glucose present:

$$\frac{0.05 \text{ grams glucose}}{\text{c. c. of sample} \times \text{Sp. grav.}} \times 100 = \text{percentage of glucose}$$

present in the prepared sample. This result may be computed upon the original sample when a dilution was made, by introducing the proper factor corresponding to the dilution.

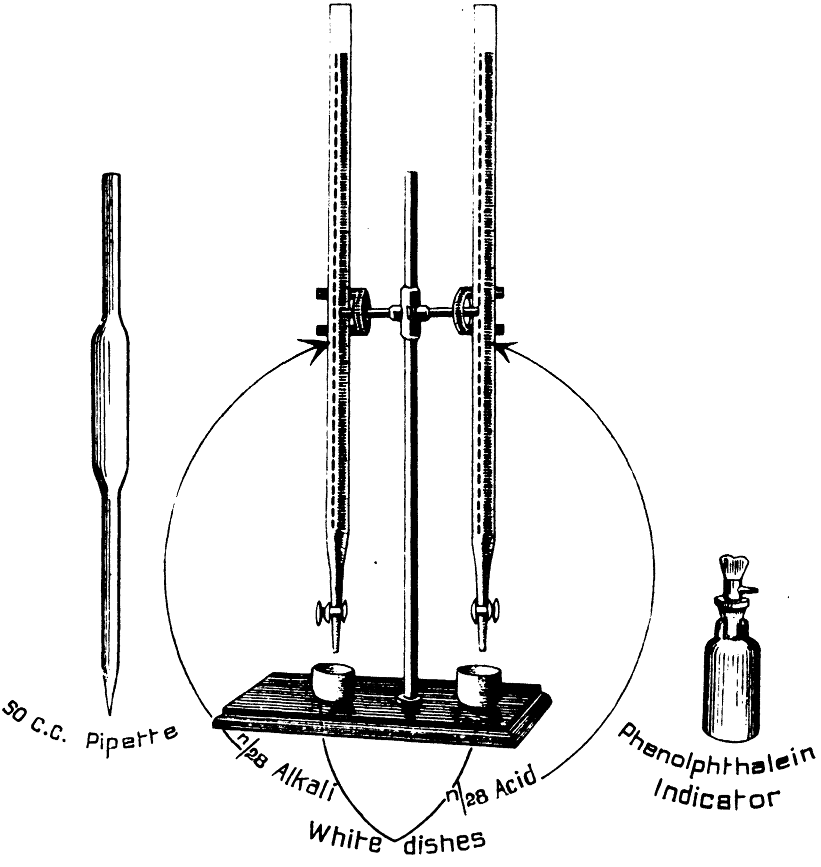


FIG. 29. Apparatus for determining acidity

DETERMINATION OF ACIDITY

The apparatus indicated in Fig. 29 is very convenient for use in this determination. A 10 c. c. calibrated pipette should be retained exclusively for this work. Measure 10 cubic centimeters of the solution to be tested into an evaporation dish or other small white container. If the specimen is very dark it should be diluted with distilled water in order to facilitate the reading of the end-point. Add two or three drops of the prepared phenolphthalein solution and carefully let in from the burette the required amount of the standard N/28 alkali or acid, as the case requires, to bring the solution to the neutral point.

This result may be recorded either as the number of cubic centimeters required to neutralize the juice or, in the case of juices and other products which are slightly acidic, as the quantity of CaO required to bring the solution to the neutral point.

ANALYSIS OF PRESS CAKE

The samples of press cake are thoroughly pulverized in case they are firm, or well beaten with a large spatula when soft cakes are being analyzed. After the specimen has been thoroughly mixed, double normal weight, or 50 grams, are carefully weighed out and washed into a 200 c. c. calibrated flask having an enlarged neck beyond the graduation mark. The sample is thoroughly dissolved in warm water, sufficient liquid lead subacetate is aded to effect clarification and after the solution is cooled to the normal temperature it is made up to the calibration mark and filtered. It is then polarized in a 200 m. m. tube and the reading multiplied by two gives the percentage of sucrose in the cake. On account of the large percentage of insoluble matter present in press cake, as well as the large precipitate formed by the addition of a large quantity of lead, the normal weight of the sample is less than that required for other sugar-house products.

The correct normal weight of ordinary press cake in cane-sugar factories approximates very nearly 25 instead of 26 grams.

ANALYSIS OF BAGASSE AND CANE

The sampling and care of this material for analysis has already been explained. The sample, after being thoroughly mixed, should be reduced to fine particles by a machine for this

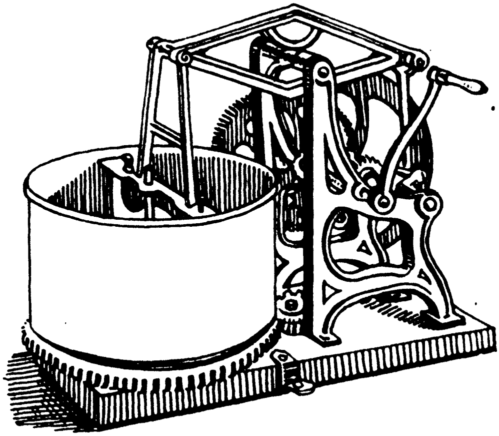


Fig. 30. Chopping machine for bagasse and cane samples

purpose, (see Fig. 30) during which time as little moisture as possible should be permitted to escape through evaporation. Consequently the work must be done with dispatch.

A steam oven may readily be installed by running a small pipe to the laboratory from one of the factory mains. A convenient design of oven is illustrated in Fig. 32. Light weight shallow alminum pans constructed of very thin material may be employed for this. One hundred grams of the finely prepared sample are weighed into one of these tared pans and dried to

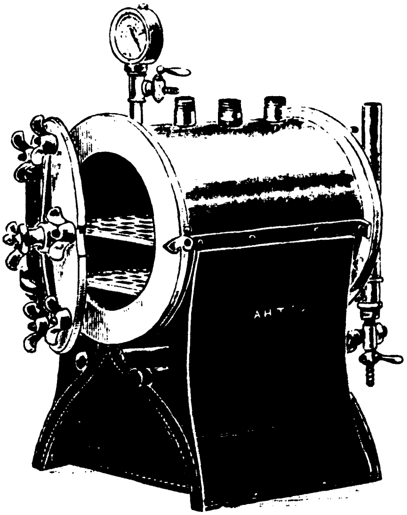


Fig. 32. Steam heated oven

constant weight in the steam oven. It is necessary to stir the sample from time in order to permit the moisture in the lower portion of the bagasse to escape. A temperature of at least 110° C will be required to drive off the last trace of moisture.

The determination of sucrose may best be made in the "Norris apparatus," which consists of a perforated metallic container supported by an outer vessel. (See Fig. 31). One hundred grams of the prepared sample are carefully weighed into the tared inner vessel and 500 cubic centimeters of water having approximately 5 cubic centimeters of a 5 per cent solution of sodium carbonate added. This is then placed in the outer vessel partly filled with water and set on the hot-plate to boil for one hour. The plunger is pushed down every fifteen minutes during the digestion. The bagasse is then pressed to remove as much of the water as possible and the inner can is set aside to cool slightly, after which it is weighed. Ninety-nine cubic centimeters of the liquor is placed in a 100 c. c. flask, made up to the 100 c. c. mark with dilute lead subacetate solution, filtered and polarized in a 400 m. m. tube.

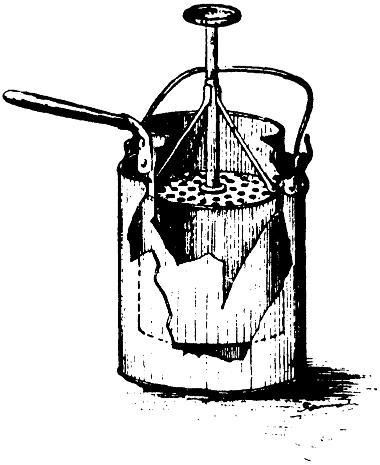


FIG. 31. Norris fiber determination apparatus

Sucrose in the sample is calculated from the following formula:

$$S=\frac{P\ (W-F)}{2 \times 3.8 \times 100}$$

S = Sucrose in sample
P = Polariscope reading
W = Weight of bagasse and solution
F = Percentage of fiber in bagasse

DETERMINATION OF ASH

Evaporate to dryness in a shallow platinum dish of at least 50 c. c. capacity 10 grams of the sample to be analyzed. It should then be heated in a muffler to a dull red heat until a white ash is obtained. This is transferred immediately to a desiccator to cool, after which it is carefully weighed. The above result is known as carbonated ash. On account of the danger of driving off volatile material during the heating, thus giving inaccurate results, the Scheibler method is more commonly used in sugar-house operations. This consists of preparing and evaporating the sample as in the previous case, after which the carbonates are changed into sulphates by saturating the ash residue with a few drops of pure concentrated sulphuric acid. The dish is again heated for a short time to a dull red heat, cooled in a desiccator, and weighed. This result must be multiplied by nine to reduce it to the carbonate form. The organic matter present in the sample is obtained by deducting the percentage of ash from the true total solids.

In control work it is seldom important to know the percentage of each chemical constituent of the ash; but in scientific research this furnishes a valuable means of tracing the source of each particular sample.

PREPARATION OF REAGENTS

The reagents used in sugar laboratory analyses consist of clarifying and precipitating reagents, standardized solutions for various analytical determinations, neutralizing reagents, indicators, etc. All of these are made up according to standard formulae, using a minimum of the various chemicals to obtain the desired result. Previous to the opening of the grinding season not only should the laboratory and each piece of apparatus therein be placed in condition for rapid and accurate work, but a good supply of the various reagents should be prepared and placed in stock also.

BASIC LEAD ACETATE, OR LEAD SUBACETATE

The preparation of this reagent requires less accuracy than that of the standardized solutions. Weigh out, using the ordinary metric dilution balance, 6.55 kilograms of commercial lead acetate and 2 kilograms of litharge; place these in a porcelain or enameled vessel and add 10 liters rain water. Set on the heating plate and keep slightly below the boiling point for about one-half hour, stirring from time to time. The mixture should then be set aside to cool and the supernatant liquor decanted and put into bottles. The same results may be obtained in preparing this reagent by setting the ingredients aside for ten or twelve hours at ordinary temperature and stirring at intervals.

The bottle from which the stock solution is taken should be of sufficient size to permit its being employed a number of days without refilling. It should be provided with a siphon arrangement consisting of a piece of rubber tube terminating in a glass tube which has been drawn to a point. The rubber tube should be provided with a stop-cock. A still better arrangement is to connect the rubber tube with a burette containing a side tube, since it is desirable to use the proper quantity of this reagent with the varying samples. The top of both the burette and the stock bottle should have a small globe of soda-lime or some other suitable substance to prevent the carbon dioxide in the air from changing the lead into the inactive or carbonate

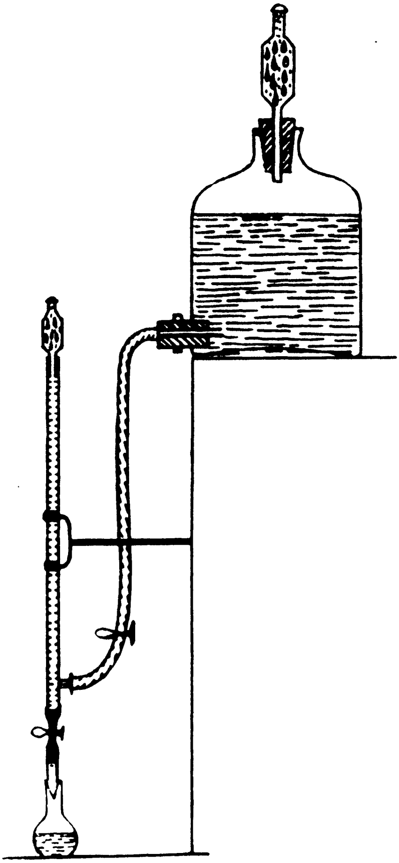


FIG. 33. Bottle provided with burette for lead subacetate solution

form. See Fig. 33. When it is prepared for use, the desired amount of this concentrated solution is drawn off and diluted to approximately 54° Brix.

ALUMINUM HYDROXIDE, OR ALUMINUM CREAM

This reagent is occasionally used in conjunction with the lead subacetate in effecting clarification and filtration, in which case the unwashed reagent is preferred, as the sulphites present assist in precipitating the excess of lead left in the solution. Where this reagent is used alone it should be thoroughly washed by decantation to remove as much as possible of the sulphites.

To prepare it, make up a saturated solution of commercial alum, pour off a small portion into another receptacle and bring the larger portion to exactly the neutral point with ammonium hydroxide. The smaller portion is then added, little by little to make the reagent but slightly acid to litmus. The precipitate is washed by decantation and placed in a stock solution bottle containing a small glass tube thrust through the stopper. After the reagent is transferred to the sample the finger is removed to permit it to flow into the solution.

This reagent finds its greatest application in improving the filtration in the preparation of white sugars for analyses.

FEHLING'S SOLUTION (SOXHLET'S)

This solution is used in making glucose determinations, hence it is imperative that it be properly made up and standardized. It is best to make up a small quantity at a time, since a slight decomposition will take place even when the copper sulphate solution is tightly stoppered and kept in a dark place. The rapidity with which this decomposition takes place is greatly accelerated when the solution is prepared for use by mixing the copper sulphate with the alkaline tartrate solution. It is, therefore, essential that this solution be mixed immediately before it is to be used.

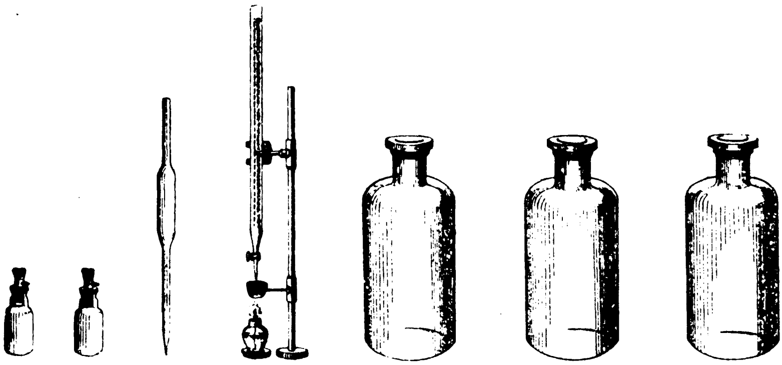


FIG. 34. Apparatus required in glucose determination

Carefully weigh out on the analytical balance 69.278 grams of chemically pure copper sulphate crystals. These are placed in a 1,000 c. c. calibrated flask, dissolved in distilled water and made up to the 1,000 c. c. mark with distilled water. This should be labeled "Copper Sulphate," or "Solution A."

The other solution should be labeled "Alkaline Tartrate," or "Solution B," and is prepared by dissolving 346 grams potassium sodium tartrate (Rochelle salts) and 102 grams sodium hydroxide in distilled water and making up to the 1,000 c. c. mark.

To standardize the above solution prepare a standard solution of invert sugar by dissolving 2.375 grams of chemically pure sucrose in 100 cubic centimeters distilled water, shake well after adding 10 cubic centimeters pure hydrochloric acid (sp. gr. 1.188), let stand over night or place the flask in a water bath for ten minutes at a temperature of exactly 70 degrees. The flask is then removed, the solution is cooled to the temperature to which the flask has been calibrated and neutralized with weak sodium hydroxide solution. It is then filled to the 1,000 c. c. mark with distilled water. Twenty cubic centimeters of this standard solution contains 0.05 grams of invert sugar. Fill a calibrated burette (see Fig. 34) to the zero mark with it, making sure that the small end of the burette beneath the stop-cock is properly filled when the first portion is removed. Have prepared an evaporating dish or casserole with exactly 10 cubic centimeters of each—the copper sulphate (solution A) and alkaline tartrate (solution B) of the Fehling solution measured with two separate calibrated pipettes having small stems and containing the necessary graduation marks. The pipettes should be kept for this specific purpose only. Place the evaporating dish or casserole over the flame and bring to the boiling point. The standard invert sugar solution is let in gradually from the burette and the copper sulphate solution is boiled for three minutes, after which tests are made with the spot plate prepared as directed under glucose determinations. The end point indicates that the copper has been reduced. Should twenty cubic centimeters be required to reduce the copper, the solution is exactly normal. However, should either more or less than the above amount be required the proper factor must be employed in making the calculations on glucose.

PHENOLPHTHALEIN SOLUTION

This forms a very convenient indicator in sugar factory work. It is made up by dissolving five grams of powdered phenolphthalein in approximately 500 cubic centimeters of water containing about 50 per cent ethyl alcohol, or by dissolving the phenolphthalein in 50 c. c. of ethyl alcohol and adding 45 c. c. of water. Where the indicator is prepared according to the above method it is extremely sensitive and for certain tests in raw-sugar control it is necessary to prepare portions of this solution slightly acidified with sulphuric acid. This solution is specially valuable in preparing phenolphthalein or Dupont paper with a degree of sensibility corresponding to different quantities of lime used in the control of the work at the liming and sulphuring stations.

ALPHA-NAPHTHOL SOLUTION

This solution is used in detecting the presence of minute traces of sucrose in the condensor and various other waste waters about the factory. While it is essentially a qualitative test, yet the presence of a large or small amount of sucrose may be observed from the intensity of the colorations formed. This solution deteriorates quite rapidly, and for this reason monthly supplies only should be prepared each time and these should be kept in dark-colored bottles.

In preparing the solution dissolve 10 grams crystallized alpha-naphthol in about 50 cubic centimeters of ethyl alcohol. This is best used from a dropping bottle, since only a very little of the solution is required in each determination. (See Fig. 35)

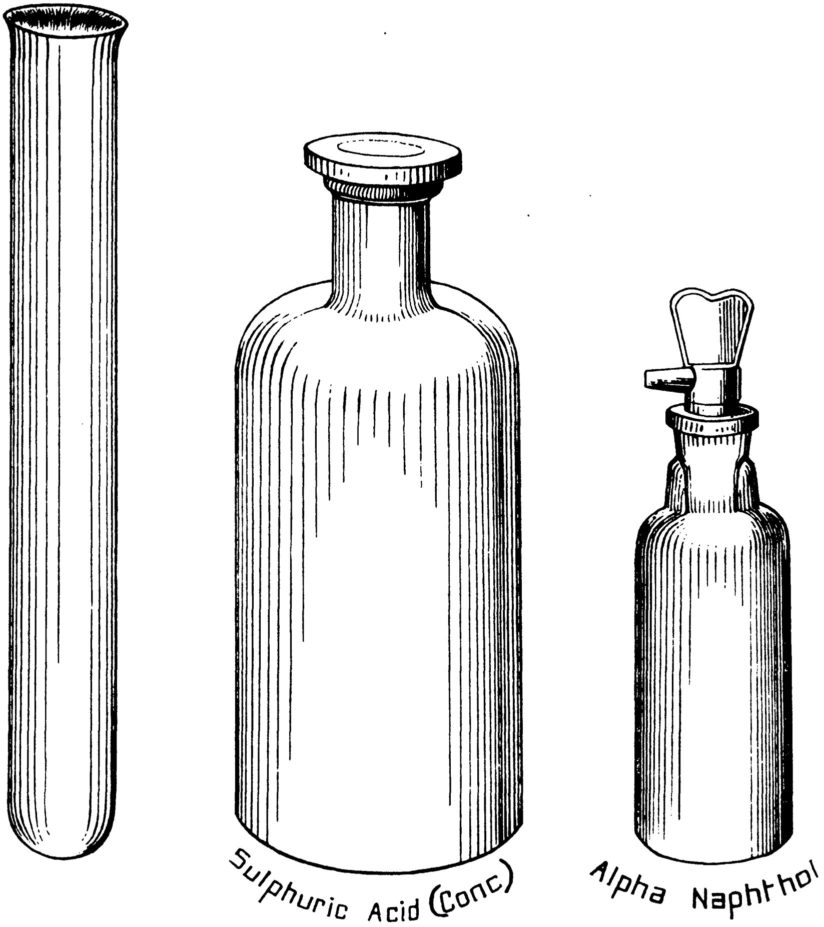


FIG. 35. Apparatus required in determining traces of sucrose

STANDARD SODIUM HYDROXIDE

Twenty-eighth normal sodium hydroxide solution is prepared by dissolving 28 grams of the chemically pure reagent in 1,000 cubic centimeters of distilled water and checking the solution against N/28 sulphuric-acid solution.

STANDARD SULPHURIC ACID

The stock solution of standard acid should be made exactly normal. This requires that 49 grams of sulphuric acid be made up to 1,000 cubic centimeters with distilled water. In testing the acidity of solutions it is desired to ascertain the amount of lime required to bring the solution to neutrality.

$$\underset{98}{H_2SO_4}\text{ (Sulphuric acid) } + \underset{56}{CaO}\text{ (Lime} = CaSO_4\text{ (Calcium sulphate) } + H_2O\text{ (Water)}$$

Since 98 grams of the sulphuric acid will be required to neutralize 56 grams of lime, or 49 grams (that contained in a normal solution) to neutralize 28 grams of lime, or a solution that is 1/28 normal to neutralize 1 gram of lime, or 1 cubic centimeter to neutralize 0.001 gram of lime, to make the N/28 solution from the N/1, dilute one hundred cubic centimeters of the latter to 2,800 cubic centimeters.

POTASSIUM OXALATE SOLUTION

This solution is used for removing the excess of lead in clarified samples for glucose determinations. It is prepared by dissolving 195 grams of neutral potassium oxalate in 100 c. c. of water.

TERMS USED TO DESIGNATE SUGAR-FACTORY PRODUCTS

CANE

This refers to the crude material as it comes from the field and includes, in addition to the stalks proper, some leaves and occasionally cane tops, dead stalks, dirt from the field and moisture. In order to determine the percentage of trash brought to the mill with the cane, a certain definite amount of the cane arriving from the wagons and cars is weighed, cleared of all trash and leaves and again weighed. The amount to be deducted from purchased cane on account of this trash is determined from the above calculations.

Fiber.—This term refers to the total insoluble material contained in the cane as it enters the mill and is determined by boiling a well prepared sample with water until no more material dissolves, after which the insoluble residue is dried to constant weight, as explained on page 154.

Water.—This refers to the total moisture contained in the cane. It is determined from the laboratory data on extraction and the amount of moisture remaining in the bagasse.

Sucrose.—This is the substance especially sought for in the various sugar factory operations. It is a carbohydrate with the formula $C_{12}H_{22}O_{11}$ and is determined by the invert or Clergét method, as explained on page 148. In routine control work comparable results may be obtained by using the direct polarization method and in that manner much valuable time is saved to the laboratory force. This reading is termed "polarization" or "sucrose by direct polarization" and the ratio of the above to the apparent solids or Brix obtained by gravity spindles is known as apparent purity. The total sucrose contained in the sugar cane is obtained by aqueous extraction of the prepared sample or the same result may be obtained by computing the sucrose extracted from the laboratory data on extraction, weight of bagasse and sucrose remaining in the bagasse.

Bagasse.—This term refers to the exhausted fibrous material resulting from the crushing of the cane.

EXTRACTION

The term extraction as commonly used in the Philippine refers to the amount of sucrose obtained in the mixed juice compared to the total sucrose contained in the cane. This is sometimes termed "sucrose extraction." Another method of expressing extraction is by computing the amount of sucrose obtained in the finished or commercial product. This might better be termed "*rendement.*" In Louisiana and Cuba the term "extraction" implies the percentage of juice obtained from the cane. This is better termed "juice extraction."

Normal juice.—This term refers to the undiluted or mixed juice coming from the mill. Originally it was intended to designate the juice that is normally contained in the cane but it has since been learned that a portion of the water in the sugar cane contains no sucrose at all. It is impossible to extract all of this water by the present methods but nevertheless the term continues to be applied to the mixed juice extracted from the cane. Where masceration or dilution water is employed, the normal or mixed juice is obtained from the following formula:

$$\frac{\text{Brix normal juice} - \text{Brix dilute juice}}{\text{Brix normal juice}} \times 100 = \text{dilution.}$$

First mill juice.—The combined juices from the first mill and the crusher, or the juice from the first mill only in case there is no crusher employed, is known as first mill juice.

Residual juice.—The juice from the last mill is known as the residual or last mill juice.

Clarified juice.—The juice which has been treated to remove the impurities and is ready for concentration is known as the clarified juice. In some factories this represents the juice coming from the subsiders, while in the factories employing a sulphuring plant it may refer to the juice coming from that station.

SYRUP

This refers to the concentrated juice leaving the effects or evaporators and ready for boiling to grain.

MASSECUITE

This is the heavy mixture leaving the vacuum pan. In boiling-house practice in the Philippine Islands it usually contains a mixture of crystals and liquid material even when lower purities are being worked, while in cooler countries the lowest grade material coming from the vacuum pan may be boiled only to "string proof" without any crystals being present. Massecuites are again divided into 1st, 2nd and 3rd types, depending upon the particular source of the original material. The 1st massecuite is produced directly from syrup, while the others are from partly exhausted materials and consist of "boil-back" from molasses obtained from previous strikes.

MOLASSES

This term refers to the liquid material obtained by separating the crystals from the liquid portion in massecuites by the aid of centrifugal machines. After the greater portion of the molasses has been separated from the crystals, it is sometimes desirable to dilute the remaining film of molasses adhering to the crystals and thus remove still greater quantities of the molasses. For this purpose water is sprayed upon the compact mass while the centrifugals are in motion and the sweet liquor obtained from this operation is termed the "wash."

SUGAR

This refers to the finished product obtained from the factory and may include 1st, 2nd and 3rd sugars.

First sugars usually include *yellow clarified* (Y. C.) or plantation white, which is simply the juice from the cane well clarified and boiled to crystals, after which the sugar is thoroughly washed, and the yellow cast from the molasses film is neutralized in the centrifugals by the aid of a bluing solution. When sugar is made for future refining, it is usually brought as nearly as possible to 96 degrees or polarization.

Second and third sugars are simply those sugars obtained from the lower grade massecuites.

FILTER PRESS MUD

This refers to the cake of impurities from the juice collected in the filter presses resulting from filtering the settlings from the defecators. The water resulting from this filtration is known as "filter press liquor" and the water used in washing the press cakes is known as "sweet water."

TOTAL SOLIDS

This term refers to the total dry matter contained in the juice and other sugar house products, and when this is determined by the drying method it is known as true solids. Where the total solids are determined by the refractometer, practically the same results are obtained as above but where gravity spindles such as Brix spindles are employed, the result is termed "Brix" or "apparent solids." Since the impurities ordinarily contained in sugar solutions have a higher specific gravity than sucrose itself and the spindles are standardized for this latter substance, the apparent solids are usually slightly higher than the true solids.

COEFFICIENT OF PURITY

The ratio of sucrose to the total solids is known as the purity of a product. Where sucrose is obtained by the invert method and the true solids by drying are employed, the result is true purity. Where sucrose is obtained by direct polarization and total solids by the gravity spindles, the result is termed apparent purity.

$$\frac{\text{Sucrose}}{\text{Total solids}} \times 100 = \text{Purity}$$

GLUCOSE COEFFICIENT

This term refers to the ratio of glucose to sucrose and the ratio offers valuable information to the factory superintendent in the management of his control work, as any change in this ratio while the product passes from station to station is indicative of the efficiency or inefficiency of the work.

If there is an increase in the glucose ratio it indicates that sucrose is being destroyed, with the resultant formation of invert sugar or glucose.

$$\frac{\text{Glucose}}{\text{Sucrose}} \times 100 = \text{Glucose ratio}$$

SALINE, OR ASH, COEFFICIENT

This refers to the ratio of sucrose to ash and is obtained by dividing the weight of sucrose by the weight of ash.

$$\frac{\text{Weight of sucrose}}{\text{Weight of ash}} \times 100 = \text{Saline coefficient}$$

TABLES

Temperature corrections for Brix spindles calibrated at 17½° C.

(Gerlach)

Temperature (degrees Centigrade).	Temperature. °F.	Observed degree Brix of solution												
		0	5	10	15	20	25	30	35	40	50	60	70	75
		CORRECTIONS TO BE SUBTRACTED FROM OBSERVED BRIX												
10	50	.20	.26	.29	.33	.36	.39	.42	.45	.48	.50	.54	.58	.61
11	51.8	.18	.23	.26	.28	.31	.34	.36	.39	.41	.43	.47	.50	.53
12	53.6	.16	.20	.22	.24	.26	.29	.31	.33	.34	.36	.40	.42	.46
13	55.4	.14	.18	.19	.21	.22	.24	.26	.27	.28	.29	.33	.35	.39
14	57.2	.12	.15	.16	.17	.18	.19	.21	.22	.22	.23	.26	.28	.32
15	59	.09	.11	.12	.14	.14	.15	.16	.17	.16	.17	.19	.21	.25
16	60.8	.06	.07	.08	.09	.10	.10	.11	.12	.12	.12	.14	.16	.18
17	62.6	.02	.02	.03	.03	.03	.04	.04	.04	.04	.04	.05	.06	.06
		CORRECTIONS TO BE ADDED TO OBSERVED BRIX												
18	64.4	.02	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.02
19	66.2	.06	.08	.08	.09	.09	.10	.10	.10	.10	.10	.10	.08	.06
20	68	.11	.14	.15	.17	.17	.18	.18	.18	.19	.19	.18	.15	.11
21	69.8	.16	.20	.22	.24	.24	.25	.25	.25	.26	.26	.25	.22	.18
22	71.6	.21	.26	.29	.31	.31	.32	.32	.32	.33	.34	.32	.29	.25
23	73.4	.27	.32	.35	.37	.38	.39	.39	.39	.40	.42	.39	.36	.33
24	75.2	.32	.38	.41	.43	.44	.46	.46	.47	.47	.50	.46	.43	.40
25	77	.37	.44	.47	.49	.51	.53	.54	.55	.55	.58	.54	.51	.48
26	78.8	.43	.50	.54	.56	.58	.60	.61	.62	.62	.66	.62	.58	.55
27	80.6	.49	.57	.61	.63	.65	.68	.68	.69	.70	.74	.70	.65	.62
28	82.4	.56	.64	.68	.70	.72	.76	.76	.78	.78	.82	.78	.72	.70
29	84.2	.63	.71	.75	.78	.79	.84	.84	.86	.86	.90	.86	.80	.78
30	86	.70	.78	.82	.87	.87	.92	.92	.94	.94	.98	.94	.88	.86

Temperature corrections for Brix spindles calibrated at 20° C.

(Browne)

Temperature (degrees Centigrade).	Observed degree Brix of Solution													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	CORRECTIONS TO BE SUBTRACTED FROM OBSERVED BRIX													
13	0.26	0.29	0.32	0.35	0.38	0.41	0.44	0.46	0.48	0.49	0.51	0.52	0.53	0.55
14	0.24	0.26	0.29	0.31	0.34	0.36	0.38	0.40	0.41	0.42	0.44	0.45	0.46	0.47
15	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.33	0.34	0.36	0.36	0.37	0.38	0.39
16	0.17	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32
17	0.13	0.14	0.15	0.16	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.23	0.24
18	0.09	0.10	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.16
19	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
	CORRECTIONS TO BE ADDED TO OBSERVED BRIX													
21	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09
22	0.10	0.10	0.11	0.12	0.12	0.13	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.16
23	0.16	0.16	0.17	0.17	0.19	0.20	0.21	0.21	0.22	0.23	0.24	0.24	0.24	0.24
24	0.21	0.22	0.23	0.24	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.32	0.32	0.32
25	0.27	0.28	0.30	0.31	0.32	0.34	0.35	0.36	0.38	0.38	0.39	0.39	0.40	0.39
26	0.33	0.34	0.36	0.37	0.40	0.40	0.42	0.44	0.46	0.47	0.47	0.48	0.48	0.48
27	0.40	0.41	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.54	0.55	0.56	0.56	0.56
28	0.46	0.47	0.49	0.51	0.54	0.56	0.58	0.60	0.61	0.62	0.63	0.64	0.64	0.64
29	0.54	0.55	0.56	0.59	0.61	0.63	0.66	0.68	0.70	0.70	0.71	0.72	0.72	0.72
30	0.61	0.62	0.63	0.66	0.68	0.71	0.73	0.76	0.78	0.78	0.79	0.80	0.80	0.81

Temperature corrections for Brix spindles calibrated at 27½° C.

Temperature, (Degrees Centigrade)	Observed degree Brix of solution									
	0	5	10	15	20	25	30	35	40	50
	CORRECTIONS TO BE SUBTRACTED FROM OBSERVED BRIX									
15	0.61	0.71	0.75	0.80	0.82	0.87	0.88	0.91	0.91	0.95
16	0.58	0.67	0.71	0.75	0.78	0.82	0.83	0.86✓	0.87	0.90
17	0.54	0.62	0.66	0.69	0.71	0.76	0.76	0.78	0.79	0.82
18	0.50	0.57	0.60	0.63	0.65	0.69	0.69	0.70	0.71	0.75
19	0.46	0.52	0.55	0.67	0.69	0.62	0.62	0.63	0.64	0.68
20	0.41	0.46	0.48	0.49	0.51	0.54	0.54	0.55	0.56	0.59
21	0.36	0.40	0.41	0.42	0.44	0.47	0.47	0.48	0.48	0.52
22	0.31	0.84	0.34	0.35	0.37	0.40	0.40	0.41	0.41	0.44
23	0.25	0.28	0.28	0.29	0.30	0.33	0.33	0.34	0.34	0.36
24	0.20	0.22	0.22	0.23	0.23	0.26	0.26	0.26	0.26	0.28
25	0.15	0.16	0.16	0.17	0.17	0.19	0.16	0.19	0.19	0.20
26	0.09	0.10	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.21
27	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04
	CORRECTIONS TO BE ADDED TO OBSERVED BRIX									
28	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
29	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12
30	0.18	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20
31	0.26	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28
32	0.34	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36
33	0.42	0.42	0.42	0.42	0.43	0.44	0.44	0.44	0.44	9.44
34	0.50	0.50	0.50	0.50	0.51	0.52	0.52	0.52	0.52	0.52
35	0.58	0.58	0.59	0.59	0.60	0.60	0.61	0.61	0.61	0.61

Table showing a comparison of the degrees Brix, Baumé, and of the specific gravity of sugar solutions at 17½° C.

(Stammer)

Degree Brix (per cent sugar)	Degree Baumé (corrected)	Specific gravity	Degree Brix (per cent sugar)	Degree Baumé (corrected)	Specific gravity	Degree Brix (per cent sugar)	Degree Baumé (corrected)	Specific gravity	Degree Brix (per cent sugar)	Degree Baumé (corrected)	Specific gravity
0.0	0.0	1.00000	23.0	13.0	1.09686	45.5	25.3	1.20832	68.0	37.1	1.33836
0.5	0.3	1.00193	23.5	13.2	1.09915	46.0	25.6	1.21100	68.5	37.4	1.34148
1.0	0.6	1.00388	24.0	13.5	1.10145	46.5	25.8	1.21369	69.0	37.6	1.34460
1.5	0.85	1.00583	24.5	13.8	1.10375	47.0	26.1	1.21639	69.5	37.9	1.34774
2.0	1.1	1.00779	25.0	14.1	1.10607	47.5	26.4	1.21910	70.0	38.1	1.35088
2.5	1.4	1.00976	25.5	14.3	1.10839	48.0	26.6	1.22182	70.5	38.4	1.35403
3.0	1.7	1.01173	26.0	14.6	1.11072	48.5	26.9	1.22455	71.0	38.6	1.35720
3.5	2.0	1.01371	26.5	14.9	1.11306	49.0	27.2	1.22728	71.5	38.9	1.36037
4.0	2.3	1.01570	27.0	15.2	1.11541	49.5	27.4	1.23003	72.0	39.1	1.36355
4.5	2.55	1.01770	27.5	15.5	1.11776	50.0	27.7	1 23278	72.5	39.4	1.36675
5.0	2.8	1.01970	28.0	15.7	1.12013	50.5	28.0	1.23555	73.0	39.6	1.36995
5.5	3.1	1.02171	28.5	16.0	1.12250	51.0	28.2	1.23832	73.5	39.9	1.37317
6.0	3.4	1.02373	29.0	16.3	1.12488	51.5	28.5	1.24111	74.0	40.1	1.37639
6.5	3.7	1.02575	29.5	16.6	1.12727	52.0	28.8	1.24390	74.5	40.4	1.37962
7.0	4.0	1.02779	30.0	16.8	1.12967	52.5	29.0	1.24670	75.0	40.6	1.38287
7.5	4.25	1.02983	30.5	17.1	1.13207	53.0	29.3	1.24951	75.5	40.9	1.38612
8.0	4.5	1.03187	31.0	17.4	1.13449	53.5	29.6	1.25233	76.0	41.1	1.38939
8.5	4.8	1.03393	31.5	17.7	1.13691	54.0	29.8	1.25517	76.5	41.4	1.39266
9.0	5.1	1.03599	32.0	17.95	1.13934	54.5	30.1	1.25801	77.0	41.6	1.39595
9.5	5.4	1.03806	32.5	18.2	1.14178	55.0	30.4	1.26086	77.5	41.9	1.39924
10.0	5.7	1.04014	33.0	18.5	1.14423	55.5	30.6	1.26372	78.0	42.1	1.40254
10.5	5.9	1.04222	33.5	18.8	1.14669	56.0	30.9	1.26658	78.5	42.4	1.40586
11.0	6.2	1.04431	34.0	19.05	1.14915	56.5	31.2	1.26946	79.0	42.6	1.40918
11.5	6.5	1.04641	34.5	19.3	1.15163	57.0	31.4	1.27235	79.5	42.9	1.41252
12.0	6.8	1.04852	35.0	19.6	1.15411	57.5	31.7	1.27525	80.0	43.1	1.41586
12.5	7.1	1.05064	35.5	19.9	1.15661	58.0	31.9	1.27816	80.5	43.3	1.41921
13.0	7.4	1.05276	36.0	20.1	1.15911	58.5	82.2	1.28107	81.0	43.6	1.42258
13.5	7.6	1.05489	36.5	20.4	1.16162	59.0	32.5	1.28400	81.5	43.8	1.42595
14.0	7.9	1.05703	37.0	20.7	1.16413	59.5	32.7	1.28694	82.0	44.1	1.42934
14.5	8.2	1.05917	37.5	21.0	1.16666	60.0	83.0	1.28989	82.5	44.3	1.43278
15.0	8.5	1.06133	38.0	21.2	1.16920	60.5	33.2	1.29284	83.0	44.6	1.43614
15.5	8.8	1.06349	38.5	21.5	1.17174	61.0	33.5	1.29581	83.5	44.8	1.48955
16.0	9.0	1.06566	39.0	21.8	1.17430	61.5	33.8	1.29878	84.0	45.1	1.44298
16.5	9.3	1.06783	39.5	22.05	1.17686	62.0	34.0	1.30177	84.5	45.3	1.44641
17.0	9.6	1.07002	40.0	22.3	1.17943	62.5	34.3	1.30476	85.0	45.5	1.44986
17.5	9.9	1.07221	40.5	22.6	1.18201	63.0	34.5	1.30777	85.5	45.8	1.45331
18.0	10.1	1.07441	41.0	22.9	1.18460	63.5	34.8	1 31078	86.0	46.0	1.45678
18.5	10.4	1.07662	41.5	23.1	1.18720	64.0	35.1	1.31381	86.5	46.3	1.46026
19.0	10.7	1.07884	42.0	23.4	1.18981	64.5	35.3	1.31684	87.0	46.5	1.46374
19.5	11.0	1.08106	42.5	23.7	1.19243	65.0	35.6	1.31989	87.5	46.7	1.46724
20.0	11.3	1.08329	43.0	23.95	1.19505	65.5	35.8	1.32294	88.0	47.0	1.47074
20.5	11.6	1.08553	43.5	24.2	1.19769	66.0	36.1	1.32601	88.5	47.2	1.47426
21.0	11.8	1.08778	44.0	24.5	1.20033	66.5	36.3	1.32908	89.0	47.45	1.47778
21.5	12.1	1.09004	44.5	24.8	1.20299	67.0	36.6	1.33217	89.5	47.7	1.48132
22.0	12.4	1.09231				67.5	36.85	1.33526	90.0	47.9	1.48486
22.5	12.7	1.09458	45.0	25.0	1.20565						

Table showing comparison of thermometer scales

Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit
100	212	62	143.6	24	75.2
99	210.2	61	141.8	23	73.4
98	208.4	60	140	22	71.6
97	206.6	59	138.2	21	69.8
96	204.8	58	136.4	20	68
95	203	57	134.6	19	66.2
94	201.2	56	132.8	18	64.4
93	199.4	55	131	17	62.6
92	197.6	54	129.2	16	60.8
91	195.8	53	127.4	15	59
90	194	52	125.6	14	57.2
89	192.2	51	123.8	13	55.4
88	190.4	50	122	12	53.6
87	188.6	49	120.2	11	51.8
86	186.8	48	118.4	10	50
85	185	47	116.6	9	48.2
84	183.2	46	114.8	8	46.4
83	181.4	45	113	7	44.6
82	179.6	44	111.2	6	42.8
81	177.8	43	109.4	5	41
80	176	42	107.6	4	39.2
79	174.2	41	105.8	3	37.4
78	172.4	40	104	2	35.6
77	170.6	39	102.2	1	33.8
76	168.8	38	100.4	0	32
75	167	37	98.6	-1	30.2
74	165.2	36	96.8	-2	28.4
73	163.4	35	95	-3	26.6
72	161.6	34	93.2	-4	24.8
71	159.8	33	91.4	-5	23
70	158	32	89.6	-6	21.2
69	156.2	31	87.8	-7	19.4
68	154.4	30	86	-8	17.6
67	152.6	29	84.2	-9	15.8
66	150.8	28	82.4	-10	14
65	149	27	80.6	-11	12.2
64	147.2	26	78.8	-12	10.4
63	145.4	25	77	-------	--------

Table showing the solubility of sucrose in water at different temperatures

(Herzfeld)

Temperature C°.	Sucrose	Temperature C°.	Sugar	Temperature C°.	Sucrose
	Per cent.		*Per cent.*		*Per cent.*
0	64.18	35	69.55	70	76.22
5	64.87	40	70.42	75	77.27
10	65.58	45	71.32	80	78.36
15	66.53	50	72.25	85	79.46
20	67.09	55	73.20	90	80.61
25	67.89	60	74.18	95	81.77
30	68.80	65	75.88	100	82.97

Properties of saturated steam below atmospheric pressure

Inches of vacuum	Temperature		Absolute pressure	Volume	Total heat from 0° F.
	Degree F.	Degree C.			
			Pounds. sq. in.	*Cubic ft. lb.*	
0	212.00	100	14.70	26.8	1178
1	210.29	99.05	14.21	27.8	1178
2	208.54	98.08	13.72	28.1	1177
3	206.73	97.07	13.22	29.0	1177
4	204.86	96.03	12.73	30.1	1176
5	202.94	94.96	12.24	31.8	1176
6	200.95	93.86	11.75	32.5	1175
7	198.89	92.72	11.26	33.7	1175
8	196.75	91.53	10.77	35.1	1174
9	194.53	90.29	10.28	36.7	1174
10	192.23	89.01	9.78	38.8	1173
11	189.81	87.67	9.30	40.4	1172
12	187.30	86.28	8.80	42.5	1171
13	184.66	84.81	8.30	44.8	1171
14	181.88	83.26	7.82	47.2	1170
15	178.96	81.64	7.33	50.8	1169
16	175.87	79.93	6.84	53.8	1168
17	172.59	78.10	6.35	58.1	1167
18	169.07	76.15	5.86	63.0	1166
19	165.31	74.06	5.36	68.2	1165
20	161.25	71.81	4.87	75.0	1164
21	156.83	69.35	4.38	83.0	1162
22	151.97	66.65	3.89	92.7	1160
23	146.55	63.64	3.41	104.0	1159
23½	143.59	61.99	3.16	112.0	1158
24	140.42	60.23	2.92	120.5	1157
24½	137.01	58.34	2.07	131.0	1156
25	133.32	56.29	2.43	143.0	1155
25½	129.31	54.06	2.17	160.0	1154
26	124.89	51.61	1.93	178.8	1153
26½	119.94	48.85	1.68	208.0	1151
27	114.34	45.74	1.44	236.8	1150
27½	107.84	42.13	1.19	282.8	1147
28	100.05	37.81	0.94	356.6	1145
28½	90.24	32.35	0.69	515.2	1142
29	76.80	24.88	0.45	660.0	1138
29½	54.21	12.34	0.21	833.0	1132

Table for computing glucose content

Weigh out 5 grams of sugar solution and make up to 100 c. c.

No. c. c. solution	Per cent glucose	No. c. c. solution	Per cent glucose	No. c. c. solution	Per cent glucose	No. c. c. solution	Per cent glucose
20	5.00	40	2.50	30	3.33	50	2.00
20.5	4.88	40.5	2.47	30.5	3.28	50.5	1.98
21	4.76	41	2.44	31	3.22	51	1.96
21.5	4.65	41.5	2.40	31.5	3.17	51.5	1.94
22	4.54	42	2.38	32	3.12	52	1.93
22.5	4.44	42.5	2.35	32.5	3.08	52.5	1.90
23	4.35	43	2.32	33	3.03	53	1.88
23.5	4.25	43.5	2.30	33.5	2.98	53.5	1.87
24	4.17	44	2.27	34	2.94	54	1.85
24.5	4.08	44.5	2.24	34.5	2.89	54.5	1.83
25	4.00	45	2.22	35	2.86	55	1.81
25.5	3.92	45.5	2.20	35.5	2.81	55.5	1.80
26	3.85	46	2.17	36	2.78	56	1.78
26.5	3.77	46.5	2.15	36.5	2.74	56.5	1.77
27	3.70	47	2.13	37	2.70	57	1.75
27.5	3.64	47.5	2.10	37.5	2.66	57.5	1.74
28	3.57	48	2.08	38	2.63	58	1.72
28.5	3.51	48.5	2.06	38.5	2.59	58.5	1.71
29	3.45	49	2.04	39	2.56	59	1.70
29.5	3.39	49.5	2.02	39.5	2.53	59.5	1.68

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 m. m. tube in a Schmitz and Haensch polariscope

Polariscope readings	Degrees Brix											Degrees Brix from 0.5 to 12.0	
	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	Per cent Surose	Degrees
Degrees													
1	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.1	0.03
2	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.2	0.06
3	0.84	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.3	0.08
4	1.12	1.12	1.12	1.11	1.11	1.11	1.11	1.11	1.10	1.10	1.10	0.4	0.11
5	1.40	1.40	1.40	1.39	1.39	1.39	1.38	1.38	1.38	1.38	1.37	0.5	0.14
6	1.68	1.68	1.67	1.67	1.67	1.66	1.66	1.66	1.66	1.65	1.65	0.6	0.17
7	1.96	1.96	1.95	1.95	1.95	1.94	1.94	1.93	1.93	1.93	1.92	0.7	0.19
8	2.24	2.24	2.23	2.23	2.22	2.22	2.22	2.21	2.21	2.20	2.20	0.8	0.22
9	2.52	2.52	2.51	2.51	2.50	2.50	2.49	2.49	2.48	2.48	2.47	0.9	0.25
10	2.80	2.80	2.79	2.79	2.78	2.78	2.77	2.76	2.76	2.75	2.75	------	------
11	3.08	3.08	3.07	3.06	3.06	3.05	3.05	3.04	3.03	3.03	3.02	------	------
12	3.36	3.36	3.35	3.34	3.34	3.33	3.32	3.32	3.31	3.30	3.30	------	------
13	3.64	3.64	3.63	3.62	3.61	3.61	3.60	3.59	3.59	3.58	3.57	------	------
14	3.92	3.92	3.91	3.90	3.89	3.88	3.88	3.87	3.86	3.85	3.85	------	------
15	4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.15	4.14	4.13	4.12	------	------
16	4.48	4.47	4.47	4.46	4.45	4.44	4.43	4.42	4.41	4.40	4.40	------	------
17	4.77	4.76	4.75	4.74	4.73	4.72	4.71	4.70	4.69	4.68	4.67	------	------
18	------	5.03	5.02	5.01	5.00	4.99	4.99	4.97	4.97	4.96	4.95	------	------
19	------	5.32	5.31	5.29	5.28	5.27	5.26	5.25	5.24	5.23	5.22	------	------
20	------	------	5.58	5.57	5.56	5.55	5.54	5.53	5.52	5.51	5.50	------	------
21	------	------	5.86	5.85	5.84	5.83	5.82	5.81	5.79	5.78	5.77	------	------
22	------	------	------	6.13	6.12	6.11	6.09	6.08	6.07	6.06	6.05	------	------
23	------	------	------	6.41	6.40	6.38	6.37	6.36	6.35	6.33	6.32	------	------
24	------	------	------	------	6.67	6.66	6.65	6.64	6.62	6.61	6.60	------	------
25	------	------	------	------	------	6.94	6.93	6.91	6.90	6.89	6.87	------	------
26	------	------	------	------	------	7.22	7.20	7.19	7.17	7.16	7.15	------	------
27	------	------	------	------	------	------	7.48	7.46	7.45	7.44	7.42	------	------
28	------	------	------	------	------	------	7.76	7.74	7.73	7.71	7.70	------	------
29	------	------	------	------	------	------	------	8.02	8.00	7.99	7.97	------	------
30	------	------	------	------	------	------	------	------	8.28	8.26	8.25	------	------
31	------	------	------	------	------	------	------	------	8.55	8.54	8.52	------	------
32	------	------	------	------	------	------	------	------	8.83	8.81	8.80	------	------
33	------	------	------	------	------	------	------	------	------	9.09	9.07	------	------
34	------	------	------	------	------	------	------	------	------	------	9.35	------	------
35	------	------	------	------	------	------	------	------	------	------	9.62	------	------

Table for calculating sucrose content of juices when clarified with lead subcetate, diluted 10 per cent and read in a 200 m. m. tube in a Schmitz and Haensch polariscope

Polariscope readings	**Degree Brix**										
	10.5	**11.0**	**11.5**	**12.0**	**12.5**	**13.0**	**13.5**	**14.0**	**14.5**	**15.0**	**15.5**
Degrees											
1	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
2	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.54	0.54	0.54
3	0.82	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
4	1.10	1.10	1.09	1.09	1.09	1.09	1.09	1.08	1.08	1.08	1.08
5	1.37	1.37	1.36	1.36	1.36	1.36	1.35	1.35	1.35	1.35	1.34
6	1.64	1.64	1.64	1.64	1.63	1.63	1.62	1.62	1.62	1.62	1.61
7	1.92	1.91	1.91	1.91	1.90	1.90	1.89	1.89	1.89	1.88	1.88
8	2.19	2.19	2.18	2.18	2.18	2.17	2.17	2.16	2.16	2.15	2.15
9	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.43	2.43	2.42	2.42
10	2.74	2.74	2.73	2.73	2.72	2.71	2.71	2.70	2.70	2.69	2.68
11	3.02	3.01	3.00	3.00	2.99	2.99	2.98	2.97	2.97	2.96	2.95
12	3.29	3.28	3.28	3.27	3.26	3.26	3.25	3.24	3.24	3.23	3.22
13	3.56	3.56	3.55	3.54	3.54	3.53	3.52	3.51	3.51	3.50	3.49
14	3.84	3.83	3.82	3.82	3.81	3.80	3.79	3.78	3.78	3.77	3.76
15	4.11	4.11	4.10	4.09	4.08	4.07	4.06	4.06	4.05	4.04	4.03
16	4.39	4.38	4.37	4.36	4.35	4.34	4.33	4.33	4.32	4.31	4.30
17	4.66	4.65	4.64	4.63	4.62	4.62	4.61	4.60	4.59	4.58	4.57
18	4.93	4.53	4.91	4.91	4.90	4.89	4.88	4.87	4.86	4.85	4.84
19	5.31	5.20	5.19	5.18	5.17	5.16	5.15	5.14	5.13	5.12	5.11
20	5.49	5.47	5.46	5.45	5.44	5.43	5.42	5.41	5.40	5.39	5.38
21	5.76	5.75	5.74	5.73	5.71	5.70	5.69	5.68	5.67	5.66	5.65
22	6.03	6.02	6.01	6.00	5.99	5.97	5.96	5.95	5.94	5.93	5.91
23	6.31	6.30	6.28	6.27	6.26	6.24	6.23	6.22	6.21	6.20	6.18
24	6.58	6.57	6.56	6.54	6.53	6.52	6.50	6.49	6.48	6.46	6.45
25	6.86	6.84	6.83	6.82	6.80	6.79	6.78	6.76	6.75	6.73	6.72
26	7.13	7.12	7.10	7.09	7.07	7.06	7.05	7.03	7.02	7.00	6.99
27	7.41	7.39	7.38	7.36	7.35	7.33	7.32	7.30	7.29	7.27	7.26
28	7.68	7.66	7.65	7.63	7.62	7.60	7.59	7.57	7.56	7.54	7.53
29	7.96	7.94	7.92	7.91	7.89	7.87	7.86	7.84	7.83	7.81	7.80
30	8.23	8.21	8.20	8.18	8.16	8.15	8.13	8.11	8.10	8.08	8.06
31	8.50	8.49	8.47	8.45	8.44	8.42	8.40	8.39	8.37	8.35	8.33
32	8.78	8.76	8.74	8.73	8.71	8.69	8.67	8.66	8.64	8.62	8.60
33	9.05	9.03	9.02	9.00	8.98	8.96	8.94	8.93	8.91	8.89	8.87
34	9.33	9.31	9.29	9.27	9.25	9.23	9.22	9.20	9.18	9.16	9.14
35	9.60	9.58	9.56	9.54	9.53	9.51	9.49	9.47	9.45	9.43	9.41
36	9.88	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72	9.70	9.68
37	10.15	10.13	10.11	10.09	10.07	10.05	10.03	10.01	9.99	9.97	9.95
38	------	10.40	10.38	10.36	10.34	10.32	10.30	10.28	10.26	10.24	10.22
39	------	10.68	10.66	10.64	10.61	10.59	10.57	10.55	10.53	10.51	10.49

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 mm. tube in a Schmitz and Haensch polariscope

Polariscope readings	Degrees Brix								
	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0
Degrees									
1	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26
2	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.53	0.53
3	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.79
4	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06
5	1.34	1.34	1.34	1.33	1.33	1.33	1.32	1.32	1.32
6	1.61	1.61	1.60	1.60	1.60	1.59	1.59	1.59	1.58
7	1.88	1.87	1.87	1.86	1.86	1.86	1.85	1.85	1.85
8	2.15	2.14	2.14	2.13	2.13	2.12	2.12	2.12	2.11
9	2.41	2.41	2.40	2.40	2.39	2.39	2.38	2.38	2.37
10	2.68	2.68	2.67	2.67	2.66	2.65	2.65	2.64	2.64
11	2.95	2.94	2.94	2.93	2.92	2.92	2.91	2.91	2.90
12	3.22	3.21	3.20	3.20	3.19	3.18	3.18	3.17	3.17
13	3.49	3.48	3.47	3.46	3.46	3.45	3.44	3.44	3.43
14	3.75	3.75	3.74	3.73	3.72	3.72	3.71	3.70	3.69
15	4.02	4.02	4.01	4.00	3.99	3.98	3.97	3.97	3.96
16	4.29	4.28	4.27	4.26	4.26	4.25	4.24	4.23	4.22
17	4.56	4.55	4.54	4.53	4.52	4.51	4.50	4.49	4.48
18	4.83	4.82	4.81	4.80	4.79	4.78	4.77	4.76	4.75
19	5.10	5.09	5.08	5.06	5.05	5.04	5.03	5.02	5.01
20	5.36	5.35	5.34	5.33	5.32	5.31	5.30	5.29	5.28
21	5.63	5.62	5.61	5.60	5.59	5.58	5.56	5.55	5.54
22	5.90	5.89	5.88	5.87	5.85	5.84	5.83	5.82	5.80
23	6.17	6.16	6.14	6.13	6.12	6.11	6.09	6.08	6.07
24	6.44	6.43	6.41	6.40	6.39	6.37	6.36	6.35	6.33
25	6.71	6.69	6.68	6.67	6.65	6.64	6.63	6.61	6.60
26	6.97	6.96	6.95	6.93	6.92	6.90	6.89	6.88	6.86
27	7.24	7.23	7.21	7.20	7.18	7.17	7.15	7.14	7.13
28	7.51	7.50	7.48	7.47	7.45	7.44	7.42	7.40	7.39
29	7.78	7.77	7.75	7.73	7.72	7.70	7.68	7.67	7.65
30	8.05	8.03	8.02	8.00	7.98	7.97	7.95	7.93	7.92
31	8.32	8.30	8.28	8.27	8.25	8.23	8.21	8.29	8.18
32	8.58	8.57	8.55	8.53	8.51	8.50	8.48	8.46	8.45
33	8.85	8.84	8.82	8.80	8.78	8.76	8.75	8.73	8.71
34	9.12	9.10	9.09	9.07	9.05	9.03	9.01	8.99	8.97
35	9.39	9.37	9.35	9.34	9.31	9.30	9.28	9.26	9.24
36	9.66	9.64	9.62	9.60	9.58	9.56	9.54	9.52	9.50
37	9.93	9.91	9.89	9.87	9.85	9.83	9.81	9.79	9.77
38	10.20	10.19	10.15	10.13	10.11	10.09	10.07	10.05	10.03
39	10.46	10.44	10.42	10.40	10.38	10.36	10.34	10.32	10.29

Degrees Brix from 0.5 to 12	
Degrees	Per cent sucrose
0.1	0.03
0.2	0.06
0.3	0.08
0.4	0.11
0.5	0.14
0.6	0.17
0.7	0.19
0.8	0.22
0.9	0.25

Degrees Brix from 12.5 to 20	
Degrees	Per cent sucrose
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.11
0.5	0.13
0.6	0.16
0.7	0.18
0.8	0.21
0.9	0.23

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 mm. tube in a Schmitz and Haensch polariscope

Polariscope readings	Degrees Brix						Degrees Brix from 11.5 to 22.5	
	11.5	12.0	12.5	13.0	13.5	14.0	Degrees	Per cent sucrose
Degrees								
40	10.93	10.91	10.89	10.86	10.84	10.82		
41		11.18	11.16	11.14	11.12	11.09	0.1	0.03
42		11.46	11.43	11.41	11.39	11.36	0.2	0.05
43			11.71	11.68	11.66	11.64	0.3	0.08
44			11.98	11.95	11.93	11.91	0.4	0.11
45			12.25	12.23	12.20	12.18	0.5	0.13
46				12.50	12.47	12.45	0.6	0.16
47					12.74	12.72	0.7	0.19
48					13.02	12.99	0.8	0.21
49						13.26	0.9	0.24

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 mm. tube in a Schmitz and Haensch polariscope

Polariscope readings	Degrees Brix						
	14.5	15.0	15.5	16.0	16.5	17.0	17.5
Degrees							
40	10.80	10.78	10.76	10.73	10.71	10.69	10.67
41	11.07	11.05	11.03	11.00	10.98	10.96	10.94
42	11.34	11.32	11.29	11.27	11.25	11.23	11.20
43	11.61	11.59	11.56	11.45	11.52	11.49	11.47
44	11.88	11.86	11.83	11.81	11.79	11.76	11.74
45	12.15	12.13	12.10	12.08	12.05	12.03	12.01
46	12.42	12.40	12.37	12.35	12.32	12.30	12.27
47	12.69	12.67	12.64	12.61	12.59	12.56	12.54
48	12.97	12.94	12.91	12.88	12.86	12.83	12.81
49	13.23	13.21	13.18	13.15	13.13	13.10	13.07
50	13.50	13.48	13.45	13.42	13.40	13.37	13.34
51	13.78	13.75	13.72	13.69	13.66	13.64	13.61
52		14.02	13.99	13.96	13.93	13.90	13.88
53		14.29	14.26	14.23	14.20	14.17	14.14
54			14.53	14.50	14.47	14.44	14.41
55			14.80	14.77	14.74	14.71	14.68
56				15.03	15.00	14.97	14.94
57				15.30	15.27	15.24	15.21
58				15.57	15.54	15.51	15.48
59					15.81	15.78	15.75
60						16.05	16.01
61						16.31	16.28
62							16.55
63							16.82

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 mm. tube in a Schmitz and Haensch polariscope

Polariscope readings	Degrees Brix						
	18.0	18.5	19.0	19.5	20.0	20.5	21.0
Degrees							
40	10.64	10.62	10.60	10.58	10.56	10.54	10.52
41	10.91	10.89	10.87	10.85	10.82	10.80	10.78
42	11.18	11.16	11.13	11.11	11.09	11.07	11.04
43	11.45	11.42	11.40	11.38	11.35	11.33	11.31
44	11.71	11.69	11.66	11.64	11.62	11.59	11.57
45	11.98	11.96	11.93	11.91	11.88	11.86	11.83
46	12.25	12.22	12.20	12.17	12.15	12.12	12.09
47	12.51	12.49	12.46	12.44	12.41	12.39	12.36
48	12.78	12.75	12.73	12.70	12.67	12.65	12.62
49	13.05	13.02	12.99	12.97	12.94	12.91	12.88
50	13.31	13.29	13.27	13.23	13.20	13.18	13.15
51	13.58	13.55	13.52	13.50	13.47	13.14	13.41
52	13.85	13.82	13.79	13.76	13.73	13.70	13.68
53	14.11	14.08	14.05	14.03	14.00	13.97	13.94
54	14.38	14.35	14.32	14.29	14.26	14.23	14.20
55	14.65	14.62	14.59	14.56	14.53	14.50	14.47
56	14.91	14.88	14.85	14.82	14.79	14.76	14.73
57	15.18	15.15	15.12	15.09	15.06	15.02	14.99
58	15.45	15.42	15.38	15.35	15.32	15.29	15.26
59	15.71	15.68	15.65	15.62	15.58	15.55	15.52
60	15.98	15.95	15.92	15.88	15.85	15.82	15.78
61	16.25	16.21	16.18	16.15	16.11	16.08	16.05
62	16.52	16.48	16.45	16.41	16.38	16.35	16.31
63	16.78	16.75	16.71	16.68	16.64	16.61	16.57
64	17.05	17.01	16.98	16.94	16.91	16.87	16.84
65	17.31	17.28	17.24	17.21	17.17	17.14	17.10
66		17.55	17.51	17.47	17.44	17.40	17.37
67		17.81	17.78	17.74	17.70	17.67	17.63
68			18.04	18.00	17.97	17.93	17.89
69			18.31	18.27	18.23	18.19	18.16
70				18.53	18.50	18.46	18.42
71					18.76	18.72	18.68
72					19.03	18.99	18.95
73						19.25	19.21
74						19.52	19.48
75						19.78	19.74
76							20.00
77							20.27

Table for calculating sucrose content of juices when clarified with lead subacetate, diluted 10 per cent and read in a 200 mm. tube in a Schmitz and Haensch polariscope.

Polariscope readings.	Degrees Brix.					
	21.5	22.0	22.5	23.0	23.5	24.0
Degrees.						
40	10.49	10.47	10.45	10.43	10.41	10.38
41	10.76	10.74	10.71	10.69	10.67	10.65
42	11.02	11.00	10.97	10.95	10.93	10.90
43	11.28	11.27	11.24	11.21	11.19	11.17
44	11.55	11.52	11.50	11.47	11.45	11.42
45	11.81	11.78	11.76	11.73	11.71	11.69
46	12.07	12.05	12.02	12.00	11.97	11.94
47	12.33	12.31	12.28	12.26	12.23	12.21
48	12.60	12.57	12.54	12.52	12.49	12.47
49	12.86	12.83	12.81	12.78	12.75	12.73
50	13.12	13.09	13.07	13.04	13.01	12.99
51	13.39	13.36	13.33	13.30	13.27	13.25
52	13.65	13.62	13.59	13.56	13.53	13.51
53	13.91	13.88	13.85	13.82	13.79	13.77
54	14.17	14.14	14.11	14.08	14.06	14.02
55	14.44	14.41	14.38	14.35	14.32	14.29
56	14.70	14.67	14.64	14.61	14.58	14.55
57	14.96	14.93	14.90	14.87	14.84	14.81
58	15.23	15.19	15.16	15.13	15.10	15.07
59	15.49	15.46	15.42	15.39	15.36	15.33
60	15.75	15.72	15.69	15.65	15.62	15.59
61	16.01	15.98	15.95	15.91	15.88	15.85
62	16.28	16.24	16.21	16.18	16.14	16.11
63	16.54	16.51	16.47	16.44	16.40	16.37
64	16.80	16.77	16.73	16.70	16.66	16.63
65	17.07	17.03	17.00	16.96	16.92	16.89
66	17.33	17.29	17.26	17.22	17.19	17.15
67	17.59	17.56	17.52	17.48	17.45	17.41
68	17.86	17.82	17.78	17.74	17.71	17.67
69	18.12	18.08	18.04	18.00	17.97	17.93
70	18.38	18.35	18.31	18.27	18.23	18.19
71	18.65	18.61	18.57	18.53	18.49	18.45
72	18.91	18.87	18.83	18.79	18.75	18.71
73	19.17	19.13	19.09	19.05	19.01	18.97
74	19.44	19.40	19.35	19.31	19.27	19.23
75	19.70	19.66	19.62	19.57	19.53	19.49
76	19.96	19.92	19.88	19.84	19.80	19.75
77	10.22	20.18	20.14	20.10	20.06	20.01
78	10.49	20.45	20.40	20.35	20.32	20.27
79	10.75	20.71	20.66	21.62	20.58	20.54
80		20.93	20.93	20.88	20.84	20.80

Degrees Brix from 11.5 to 22.5.	
De-grees.	Per cent sucrose.
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.11
0.5	0.13
0.6	0.16
0.7	0.19
0.8	0.21
0.9	0.24

Degrees Brix from 23.0 to 24.0.	
De-grees.	Per cent sucrose.
0.1	0.03
0.2	0.05
0.3	0.08
0.4	0.10
0.5	0.13
0.6	0.16
0.7	0.18
0.8	0.21
0.9	0.23

Table for calculating sucrose content of juices clarified with dry lead subacetate and read in a 200 mm. tube in a Schmitz and Haensch polariscope

(Horne's method.)

Polariscope readings.	Degrees Brix and per cent sucrose.																			
	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0
Degrees.																				
1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
2	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
3	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.72	0.72
4	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96
5	1.25	1.25	1.25	1.24	1.24	1.24	1.24	1.24	1.23	1.23	1.23	1.22	1.22	1.22	1.22	1.21	1.21	1.21	1.21	1.20
6	1.50	1.50	1.50	1.49	1.49	1.49	1.48	1.48	1.48	1.48	1.47	1.47	1.46	1.46	1.46	1.45	1.45	1.45	1.45	1.44
7	1.75	1.75	1.75	1.74	1.74	1.74	1.73	1.73	1.72	1.72	1.71	1.71	1.70	1.70	1.69	1.69	1.69	1.69	1.69	1.68
8	2.00	2.00	1.99	1.98	1.98	1.98	1.98	1.97	1.97	1.97	1.96	1.96	1.95	1.95	1.94	1.94	1.94	1.93	1.93	1.92
9	2.25	2.24	2.24	2.24	2.24	2.24	2.23	2.22	2.22	2.21	2.21	2.21	2.20	2.20	2.19	2.19	2.18	2.18	2.17	2.16
10	2.50	2.49	2.49	2.48	2.48	2.48	2.47	2.47	2.46	2.46	2.45	2.45	2.44	2.44	2.43	2.43	2.42	2.42	2.41	2.41
11	2.75	2.74	2.73	2.73	2.72	2.72	2.71	2.71	2.70	2.70	2.69	2.68	2.68	2.67	2.67	2.67	2.66	2.66	2.65	2.64
12	3.00	2.99	2.98	2.98	2.97	2.97	2.96	2.96	2.95	2.95	2.94	2.93	2.93	2.92	2.92	2.91	2.91	2.90	2.89	2.89
13	3.25	3.24	3.23	3.23	3.22	3.21	3.20	3.20	3.19	3.19	3.18	3.17	3.17	3.16	3.16	3.15	3.14	3.14	3.13	3.13
14	3.50	3.50	3.49	3.48	3.47	3.46	3.45	3.45	3.44	3.43	3.42	3.42	3.41	3.41	3.41	3.40	3.39	3.38	3.37	3.37
15	3.75	3.74	3.73	3.72	3.71	3.71	3.70	3.69	3.69	3.68	3.67	3.66	3.66	3.65	3.65	3.64	3.63	3.62	3.62	3.61
16	4.00	3.99	2.98	3.97	3.96	3.96	3.95	3.94	3.94	3.93	3.92	3.91	3.90	3.88	3.88	3.88	3.87	3.86	3.85	3.85
17	4.25	4.25	4.23	4.22	4.21	4.20	4.19	4.19	4.18	4.17	4.16	4.15	4.14	4.12	4.12	4.12	4.11	4.11	4.10	4.09
18	4.50	4.49	4.48	4.47	4.46	4.45	4.44	4.44	4.43	4.42	4.41	4.40	4.39	4.37	4.37	4.37	4.35	4.35	4.34	4.33
19	4.75	4.74	4.73	4.72	4.71	4.70	4.69	4.68	4.67	4.66	4.65	4.64	4.63	4.61	4.61	4.61	4.60	4.59	4.58	4.57
20	5.00	4.99	4.98	4.97	4.96	4.95	4.94	4.93	4.92	4.91	4.90	4.89	4.88	4.86	4.86	4.85	4.84	4.83	4.82	4.81
21	5.25	5.23	5.22	5.21	5.20	5.19	5.18	5.17	5.16	5.15	5.14	5.13	5.12	5.10	5.10	5.09	5.08	5.07	5.06	5.05
22	5.50	5.48	5.47	5.46	5.42	5.44	5.43	5.42	5.41	5.40	5.39	5.38	5.37	5.35	5.35	5.34	5.32	5.31	5.30	5.29
23	5.75	5.73	5.72	5.71	5.70	5.69	5.68	5.67	5.66	5.65	5.64	5.62	5.61	5.59	5.58	5.58	5.56	5.55	5.54	5.53
24	6.00	5.98	5.97	5.96	5.95	5.94	5.93	5.92	5.91	5.90	5.89	5.87	5.86	5.84	4.83	5.82	5.81	5.80	5.79	5.77
25	6.25	6.23	6.22	6.21	6.20	6.18	6.17	6.16	6.15	6.14	6.13	6.11	6.10	6.08	6.07	6.06	6.05	6.04	6.03	6.01
26	6.50	6.49	6.48	6.46	6.44	6.43	6.42	6.41	6.40	6.39	6.38	6.36	6.34	6.33	6.32	6.30	6.29	6.28	6.27	6.26
27	6.75	6.74	6.72	6.70	6.69	6.68	6.67	6.65	6.64	6.63	6.62	6.60	6.59	6.57	6.56	6.55	6.54	6.52	6.51	6.50
28	7.00	6.98	6.97	6.95	6.94	6.93	6.93	6.90	6.89	6.87	6.86	6.85	6.84	6.82	6.81	6.79	6.78	6.77	6.75	6.74
29	7.25	7.23	7.22	7.20	7.19	7.17	7.16	7.15	7.14	7.12	7.11	7.09	7.08	7.06	7.05	7.03	7.02	7.01	6.99	6.98
30	7.50	7.48	7.47	7.45	7.44	7.42	7.41	7.40	7.39	7.37	7.35	7.34	7.33	7.31	7.29	7.27	7.26	7.25	7.23	7.22
31	7.75	7.73	7.71	7.70	7.68	7.66	7.65	7.64	7.63	7.61	7.60	7.58	7.57	7.55	7.53	7.51	7.50	7.49	7.47	7.46
32	8.00	7.98	7.96	7.95	7.93	7.91	7.90	7.89	7.88	7.86	7.84	7.82	7.81	7.79	7.78	7.76	7.75	7.73	7.71	7.70
33	8.25	8.23	8.21	8.20	8.18	8.16	8.15	8.13	8.12	8.10	8.09	8.07	8.05	8.03	8.01	8.00	7.99	7.97	7.95	7.94

Degrees Brix from 0.5 to 12.0.	
Tenths of the polariscope reading.	Per cent sucrose.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.20
0.9	0.22

Degrees Brix from 12.0 to 20.0.	
Tenths of the polariscope reading.	Per cent sucrose.
0.1	0.02
0.2	0.05
0.3	0.07
0.4	0.10
0.5	0.12
0.6	0.15
0.7	0.17
0.8	0.19
0.9	0.22

34	8.50	8.48	8.47	8.45	8.43	8.41	8.40	8.38	8.37	8.35	8.34	8.32	8.30	8.28	8.26	8.24	8.23	8.22	8.20	8.18
35	8.75	8.73	8.71	8.69	8.68	8.66	8.65	8.63	8.61	8.59	8.58	8.56	8.54	8.52	8.50	8.48	8.47	8.46	8.44	8.42
36	9.00	8.98	8.96	8.94	8.92	8.91	8.90	8.88	8.66	8.84	8.82	8.80	8.78	8.76	8.75	8.73	8.71	8.70	8.68	8.66
37	9.25	9.23	9.21	9.19	9.17	9.15	9.14	9.12	9.10	9.08	9.07	9.05	9.03	9.01	8.99	8.97	8.95	8.94	8.92	8.90
38	9.50	9.48	9.46	9.44	9.42	9.40	9.39	9.37	9.35	9.33	9.31	9.29	9.27	9.26	9.24	9.21	9.20	9.18	9.16	9.14
39	9.75	9.73	9.71	9.69	9.67	9.65	9.64	9.62	9.60	9.58	9.55	9.53	9.51	9.50	9.48	9.46	9.44	9.43	9.40	9.38

Table for calculating sucrose content of juices clarified with dry lead subacetate and read in a 200 mm. tube in a Schmitz and Haensch polariscope

(Horne's method.)

Polariscope readings.	Degrees Brix and per cent sucrose.																	Degrees Brix from 11.5 to 22.5	
	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	Tenths of the polariscope reading.	Per cent sucrose.
Degrees.																			
40	9.96	9.94	9.92	9.90	9.88	9.86	9.84	9.82	9.80	9.78	9.76	9.74	9.72	9.70	9.68	9.66	9.64	0.1	0.02
41	10.20	10.18	10.17	10.15	10.12	10.10	10.08	10.06	10.04	10.02	10.00	9.98	9.96	9.94	9.92	9.90	9.88	0.2	0.05
42	10.45	10.43	10.42	10.40	10.37	10.35	10.33	10.31	10.29	10.26	20.24	10.22	10.20	10.18	10.16	10.14	10.12	0.3	0.07
43	10.70	10.68	10.67	10.65	10.62	10.60	10.58	10.56	10.53	10.51	20.49	10.47	10.44	10.42	10.41	10.38	10.36	0.4	0.10
44	10.95	10.93	10.91	10.89	10.86	10.85	10.83	10.81	10.78	10.76	10.74	10.72	10.69	10.67	10.65	10.63	10.60	0.5	0.12
45	11.20	11.18	11.16	11.14	11.11	11.09	11.07	11.05	11.02	11.00	10.98	10.96	10.93	10.91	10.89	10.87	10.85	0.6	0.15
46		11.43	11.41	11.39	11.36	11.34	11.32	11.29	11.27	11.25	11.23	11.20	11.18	11.16	11.14	11.11	11.08	0.7	0.17
47		11.67	11.66	11.63	11.61	11.59	11.56	11.54	11.51	11.49	11.47	11.44	11.42	11.40	11.37	11.35	11.30	0.8	0.19
48			11.90	11.89	11.86	11.84	11.81	11.79	11.76	11.74	11.72	11.69	11.66	11.64	11.62	11.59	11.56	0.9	0.22
49			12.15	12.13	12.10	12.08	12.05	12.03	12.00	11.98	11.96	11.93	11.90	11.88	11.86	11.83	11.80		
50				12.38	12.35	12.33	12.30	12.28	12.25	12.23	12.20	12.18	12.15	12.13	12.10	12.08	12.05		
51				12.63	12.60	12.57	12.54	12.52	12.49	12.47	12.44	12.42	12.39	12.37	12.34	12.32	12.29		
52					12.85	12.82	12.79	12.77	12.74	12.71	12.69	12.67	12.63	12.62	12.58	12.56	12.53		
53					13.09	12.07	13.04	13.01	12.99	12.96	12.93	12.91	12.87	12.86	12.83	12.80	12.77		
54						13.32	13.29	13.26	13.24	13.20	13.18	13.15	13.12	13.11	13.07	13.04	13.01		
55						13.56	13.53	13.50	13.48	13.44	13.42	13.39	13.36	13.34	13.31	13.28	13.25		
56							13.78	13.75	13.73	18.69	13.66	13.64	13.61	13.58	13.55	13.52	13.50		
57							14.02	13.99	13.97	13.93	13.90	13.88	13.85	13.82	13.79	13.76	13.74		
58								14.24	14.21	14.18	14.15	14.12	14.09	14.07	14.04	14.01	13.98		
59								14.48	14.45	14.42	14.39	14.36	14.33	14.31	14.28	14.25	14.22		
60									14.70	14.67	14.64	14.61	14.58	14.55	14.52	14.49	14.46		
61									14.95	14.91	14.88	14.85	14.82	14.79	14.76	14.73	14.70		
62										15.16	15.13	15.10	15.07	15.04	15.00	14.97	14.94		
63										15.40	15.37	15.34	15.31	15.28	15.24	15.21	15.18		
64										15.65	15.62	15.59	15.56	15.53	15.49	15.46	15.43		
65											15.86	15.83	15.80	15.77	15.73	15.70	15.67		
66											16.10	16.07	16.04	16.01	15.97	15.94	15.91		
67												16.31	16.28	16.25	16.21	16.18	16.15		
68													16.52	16.49	16.46	16.43	16.39		
69													16.77	16.73	16.70	16.67	16.63		
70													17.01	16.98	16.94	16.91	16.87		

71														17.22	17.18	17.15	17.11
72																17.39	17.35
73																17.63	17.59
74																17.87	17.83
75																18.11	18.08
76																18.35	18.32

FORMULAE FOR THE SUGAR LABORATORY

The following formulae with the accompanying examples reported in the Hawaiian Planters' Record, Vol. 11, 1910, will prove very useful, especially for new assistants, in making the various calculations of sugar factory products.

SECTION I

RELATIONS BETWEEN BRIX, SUCROSE, AND PURITY

(1) $P=\frac{100S}{B}$

Example.—Sucrose=43.79%, and Brix=72.5; then Purity=

$$\frac{43.79\times 100}{72.5}=60.4$$

(2) $S=\frac{P\times B}{100}$

Example.—Purity=60.4, and Brix=72.5; then Sucrose=

$$\frac{60.4\times 72.5}{100}=43.79$$

(3) $B=\frac{100S}{P}$

Example.—Sucrose=43.79, and Purity=60.4; then Brix=

$$\frac{100\times 43.79}{60.4}=72.5$$

SECTION II

PROBLEMS RELATING TO MIXTURES

The problems given in this section are typical of the greater part which must be solved in a sugar factory.

PROBLEM 1.—Given a product containing P per cent of a given substance, what quantity of water must be added to, or taken away from, 100 parts of this product, in order that the resulting mixture contains P′ per cent of the given substance?

(*a*) In case of the addition of water, P^1 is less than P, and $X=\frac{100\ (P^1\text{-}P)}{P^1}$

Example.—How much water must be added to 100 pounds of a molasses of 80 Brix, to lower it to 60 Brix?

$$\frac{100\ (80-60)}{60}=33.3 \text{ pounds of water}$$

(*b*) In case of the removal of water, P′ is greater than P, and $X=\frac{100\ (P^1\text{-}P)}{P^1}$

Example.—How much water must be evaporated from 100 pounds of syrup of 60 Brix to make a massecuite having 95 Brix?

$$\frac{100\ \ (95-60)}{95}=36.8 \text{ pounds}$$

How much water must be evaporated from 100 pounds of press cake having 15% solid matter, to leave it with 75% solid matter?

$$\frac{100\ (75-15)}{75}=80 \text{ pounds}$$

How much sucrose can be removed from 100 pounds of a massecuite containing 3.13% ash, if the molasses therefrom contains 6.34% ash, supposing that nothing but pure sucrose is removed?

$$\frac{10\ (6.34-3.13)}{6.34}=50.6 \text{ pounds}$$

PROBLEM 2.—If a substance contains P per cent of a given given matter A, and the percentage becomes P′ by the removal or addition of a substance other than, A, what is the percentage of the new product on the original?

$$X=\frac{100P}{P'}$$

Examples.—A juice has 14.5 Brix, and the syrup therefrom 71.5 Brix. How much syrup is there per 100 pounds juice?

$$\frac{100\times 14.5}{71.5}=20.3 \text{ pounds}$$

A cane contains 10% fiber, and the bagasse therefrom 40% fiber. How much bagasse is there per 100 tons cane?

$$\frac{100\times 10}{40}=25 \text{ tons}$$

A massecuite contains 7.84 per cent ash, and the molasses from it contains 10.15 per cent. How much molasses is there in 100 pounds massecuite?

$$\frac{100\times 7.84}{10.15}=77.2 \text{ pounds}$$

PROBLEM 3.—Given a substance containing P per cent of a given matter A to which is added or subtracted per 100 parts of water or material other than A, what per cent of A does the new product contain?

$$\text{In case of addition, } X=\frac{100P}{100+a}$$

Example.—To 100 gallons of juice containing 135 pounds of sugar, 7 gallons of water are added. How much sugar do 100 gallons of the mixture contain?

$$\frac{100\times 135}{100+7}=126.1 \text{ pounds}$$

$$\text{In case of subtraction, } X=\frac{100P}{100-a}$$

Example.—107 gallons of juice containing 126.1 pounds of sugar are evaporated to 100 gallons. How much sugar does this contain?

$$\frac{107\times 126.1}{100-7}=134.93 \text{ pounds}$$

PROBLEM 4.—Given a product containing P per cent in weight of a substance A, how much of A must be added to, or subtracted from, 100 parts in weight of the first product, in order that the percentage in weight of the substance A in the new product becomes P^1.

$$\text{In case of addition, } X=\frac{100\ (P^1-P)}{100-P^1}$$

Example.—A solution contains 25 per cent sugar by weight. How much sugar must be added to 100 grams of this solution so that the percentage shall be 30?

$$\frac{100\ (30-25)}{100-30}=7.14\text{ grams}$$

$$\text{In the case of subtraction, } X=\frac{100\ (P-P^1)}{100-P^1}$$

Examples.—A massecuite contains 75 per cent of sugar. How much sugar must be removed from 100 pounds of such a massecuite, in order that the molasses should contain 54 per cent?

$$\frac{100\ (75-54)}{100-54}=45.6\text{ pounds}$$

Given a molasses of 74 purity, how much sucrose must be recovered from 100 pounds of dry matter in that product to lower the purity to 60?

$$\frac{100\ (74-60)}{100-60}=35\text{ pounds}$$

(The purity of a substance being the quantity of sucrose per cent of dry matter in that substance, it is necessary, in order to apply the last formula, to presume that the product is 100 Brix, or contains no moisture. By a simple rule of proportion, this can be referred back to the initial product.)

If a bagasse contains 60% water, how much water must be removed by dessication from 100 grams in order that the percentage of moisture shall become 30 per cent?

$$\frac{100\ (60-30)}{100-30}=42.8$$

PROBLEM 5.—Given a substance containing P per cent by weight of a given matter A, to which is added or subtracted a certain quantity of A making its percentage in the mixture P,′ what quantity of the new product is obtained per 100 of the original?

$$X=\frac{100\ (100-P)}{100-P'}$$

Example.—To 100 pounds of molasses containing 10% water, enough water is added so that its percentage becomes 25%. How much dilute molasses is there?

$$\frac{100\ (100-10)}{100-25}=120\text{ pounds}$$

A massecuite contains 74% sucrose and its molasses 60% sucrose. How much molasses is there per 100 massecuite.

$$\frac{100\ (100-74)}{100-60}=65$$

A press cake contains 85% water; after drying it contains 8%. How many pounds of this dry cake result from 100 pounds of the wet?

$$\frac{100\ (100-85)}{100-8}=16.3 \text{ pounds}$$

PROBLEM 6.—Given a product containing P per cent of a substance A, to 100 parts by weight of which are substracted or added a parts by weight of A, what is the new percentage of A?

$$\text{For subtraction } X=\frac{100\ (P-a)}{100-a}$$

***Example.*—From a massecuite containing 85 per cent total solids are removed 35 per cent of pure sucrose. What per cent of total solids does the resulting molasses contain?**

$$\frac{100\ (85-35)}{100-35}=76.92$$

$$\text{For addition } X=\frac{100\ (P+a)}{100+a}$$

***Example.*—To 100 pounds of juice containing 14 per cent sucrose, 10 per cent of sucrose is added. What is the percentage of sucrose of the mixture?**

$$\frac{100\ (14+10)}{100+10}=21.82 \text{ per cent}$$

PROBLEM 7.—Given a product containing P per cent of a given substance A, what quantity of a product having P″ per cent of A must be added to, or taken away from, 100 parts of the first product, in order to obtain a new product having P′ per cent of A?

In case of addition,

$$\text{when } P'' > P' > P,\ X=\frac{100\ (P'-P)}{P''-P'}$$

$$\text{when } P'' < P' < P,\ X=\frac{100\ (P-P')}{P'-P''}$$

***Example.*—A lot of sugar contains 94% sucrose. How much sugar containing 97.8% sucrose must be added to 100 tons of the first sugar, in order to obtain a mixture containing 96% sucrose?**

$$\frac{100\ (96-94)}{97.8-96}=111.11 \text{ tons}$$

Given a molasses having 85 Brix, how much juice of 15 Brix must be added to 100 pounds of the molasses, in order to obtain a mixture having 55 Brix?

$$\frac{100\ (85-55)}{55-15}=75 \text{ pounds}$$

In case of subtraction,

$$\text{when } P'' > P > P',\ X=\frac{100\ (P-P')}{P''-P'}$$

$$\text{when } P'' < P < P',\ X=\frac{100\ (P'-P)}{P'-P''}$$

Example.—A massecuite contains 3.64% ash. How much molasses containing 7.03% ash must be removed from 100 pounds to leave a sugar containing 0.40% ash?

$$\frac{100\ (3.64-40)}{7.03-.40}=48.9 \text{ pounds}$$

In the same example, how much sugar is obtained per 100 pounds massecuite?

$$\frac{100\ (7.03-3.64)}{7.03-.40}=51.1 \text{ pounds}$$

PROBLEM 8.—Given a product containing P per cent of a given substance A, to which are added or subtracted a certain quantity of a product containing P″ per cent of A, making the new product contain P″ per cent of A, how much of the new product is there per 100 of the original?

$$1^\circ-\left.\begin{array}{l} P'' > P' > P \\ P'' > P > P' \end{array}\right\}X=\frac{100\ (P''-P)}{P''-P'}$$

$$2^\circ-\left.\begin{array}{l} P > P' > P'' \\ P' > P > P'' \end{array}\right\}X=\frac{100\ (P-P'')}{P'-P''}$$

Examples for this problem may be taken from Problem 7. Thus, given 100 tons of sugar containing 94% sucrose, to which is added sufficient sugar containing 97.8% sucrose to yield a mixture containing 96% sucrose. How much of the mixture results?

$$\frac{100\ (97.8-94)}{97.8-96}=211.11 \text{ tons}$$

PROBLEM 9.—Given a product containing P per cent of a substance A, to 100 parts by weight of which are added or subtracted a parts by weight of a substance having P′ per cent of A, what percentage of A does the resulting product contain?

$$\text{Addition } X=\frac{100\ (P+aP')}{100+a}$$

Example.—100 pounds of second sugar containing 8% moisture (i. e., 92 Brix), are dissolved in 75 pounds juice having 15 Brix. What is the Brix of the solution?

$$\frac{100\times 92+75\times 15}{100+75}=59 \text{ Brix}$$

Example.—To 100 pounds of a dilute molasses of 60 purity are added 25 pounds of syrup of 93 purity and the same Brix as the dilute molasses. What is the purity of the mixture?

$$\frac{100\times 60+25\times 93}{100+25}=66.6 \text{ purity}$$

$$\text{Subtraction } X=\frac{100\ (P-aP')}{100-a}$$

Example.—From 100 tons of a massecuite containing 92% total solids, are recovered 44 tons of sugar containing 98% total solids. What are the total solids per cent molasses?

$$\frac{100\times 92-44\times 98}{100-44}=87.3$$

PROBLEM 10.—Given a substance containing P per cent of a matter A, what quantity of water (or material other than A) must be added to, or taken from P′ parts of that substance, in order that the new product shall contain P′ per cent of A?

$$\text{For addition } X=P-P'$$
$$\text{For subtraction, } X=P'-P$$

Example.—It is desired to reduce a syrup of 60 Brix to 13 Brix with water. To each 13 parts of syrup must be added 60−13=47 parts of water.

SECTION III

A—DENSITY PROBLEMS

In the following problems are established formulae which allow the determination of the different questions of mixture in terms of specific gravity. In practice, this can be replaced by density, which usually gives sufficiently accurate results. This remark applies to all problems where the density is used in passing from volume to weight.

PROBLEM 11.—Given a volume V of a product of density D, how much water must be added, or subtracted, to make the density D?

$$\text{In case of addition, } X=\frac{V\ (D-D')}{D'-1}$$

Example.—Given 100 gallons of caustic soda solution of 1.298 specific gravity. How much water must be added to reduce it to 1.163 specific gravity?

$$\frac{100\ (1.298-1.163)}{1.163-1}=82.8 \text{ gallons}$$

$$\text{In case of subtraction, } X=\frac{V'\ (D'-D)}{D'-1}$$

Example.—Given 5,200 gallons of juice of 1.059 density, how much water must be evaporated therefrom to obtain a syrup of 1.28 density?

$$\frac{5{,}200\ (1.28-1.059)}{1.28-1}=4104.3 \text{ gallons}$$

PROBLEM 12.—Given a volume V of a product of density D to which is added, or from which is removed, water to make the density D′, what is the volume of product obtained?

$$X=\frac{V\ (D-1)}{D'-1}$$

Example.—Having 100 gallons of caustic soda solution of 1.298 specific gravity, and having reduced it with water to 1.163 specific gravity, what is the volume of the mixture?

$$\frac{100\ (1.298-1)}{1.163-1}=182.8 \text{ gallons}$$

If 5,200 gallons of juice of 1.059 density are evaporated to 1.28 density, what volume of syrup is obtained?

$$\frac{5{,}200\ (1.059-1)}{1.28-1}=1{,}095.7 \text{ gallons}$$

PROBLEM 13.—Given a volume V of a liquid of density D to which is added, or subtracted, a volume A of water, what is the density of the resulting product?

$$\text{In case of addition, } X=\frac{V\ D+a}{V+a}$$

Example.—1,500 gallons of molasses of 1.4 density are diluted with 1,200 gallons of water. What is the density of the mixture?

$$\frac{(1{,}500\times1.4)+1{,}200}{1{,}500+1{,}200}=1.222$$

$$\text{In case of subtraction, } X=\frac{V\ D-a}{V-a}$$

Example.—50,000 gallons of juice of 1.06 density are evaporated to 10,000 gallons syrup. What is the density of the latter? In this case, $a=50{,}000-10{,}000=40{,}000$.

$$\frac{(50{,}000\times1.06)-40{,}000}{50{,}000-40{,}000}=1.30$$

PROBLEM 14.—Given a volume V of liquid of density D, to which is added a volume V′ of a liquid density D′, what is the density of the resulting product?

$$X=\frac{V\ D+V'\ D'}{V+V'}$$

Example.—What is the density of a mixture of 1,000 gallons of syrup of 1.29 density and 500 gallons of molasses of 1.42 density?

$$\frac{(100\times1.29)+(500\times1.42)}{1{,}000+500}=1.333$$

Problem 15.—With several liquids of volumes V, V', V'', etc., with corresponding densities of D, D' D'', etc., the density of the mixture will be:

$$X=\frac{V\ D+V'\ D'+V''\ D''+\text{etc.}}{V+V'+V''+\text{etc.}}$$

B—PURITY PROBLEMS

Remark.—All the formulae apply to both real and apparent values; for absolutely exact results, however, the real values are essential.

Problem 16.—How much of a product of P'' purity must be added to 100 parts by weight of a product of P purity and the same Brix (or density), in order to obtain a produce of P' purity?

When P'' is greater than P, $X=\dfrac{100\ (P'-P)}{P''-P'}$

Example.—A syrup has a purity of 88. How much of this must be added to 100 pounds of a diluted molasses of the same Brix and 50 purity, in order that the purity of the mixture should be 75?

$$\frac{100\ (75-50)}{90-75}=166.7 \text{ pounds}$$

When P'' is less than P, $X=\dfrac{100\ (P-P')}{P'-P''}$

Example.—A syrup has a purity of 91. How much molasses, diluted to the same Brix and of a purity of 45, must be added to 100 pounds of the syrup, in order to reduce its purity to 80?

$$\frac{100\ (91-80)}{80-45}=31.4 \text{ pounds}$$

Problem 17.—In what proportions must a product of P purity be mixed with one of P'' purity, but of the same Brix (or density), in order to obtain a product of P' purity?

If P'' is less than P, it is necessary to take $P'-P''$ parts of the product of P purity and $P-P'$ parts of the product of P'' purity.

Example.—In what proportions must a syrup of 93 purity be mixed with a molasses of 75 purity, to obtain a mixture of 90 purity?

Take $90-75=15$ parts of syrup to $93-90=3$ parts of molasses.

Problem 18.—What quantity of a product of B'' Brix and P'' purity must be added to 100 parts by weight of a product of B Brix and P purity, to obtain a product of P' purity?

If P'' is greater than P, $X=\dfrac{100\,B\ (P'-P)}{B''\ (P''-P')}$

Example.—How much syrup of 60 Brix and 90 purity must be added to 2,025 pounds of molasses of 80 Brix and 50 purity to bring the mixture to 60 purity?

$$\frac{2{,}025\times 80\ (60-50)}{60\ (90-60)}=900 \text{ pounds}$$

$$\text{If } P'' \text{ is less than } P,\ X=\frac{100\ (P-P')}{B''\ (P'-P'')}$$

Example.—To 1,000 pounds of a massecuite of 94 Brix and 93 purity, how much molasses of 85 Brix and 75 purity must be added, in order to have a mixture of 83 purity?

$$\frac{1{,}000\times 94\ (93-83)}{85\ (83-75)}=1{,}382.3 \text{ pounds}$$

Problem 19.—What is the purity of the mixture of a volume V of a product of B Brix and D density, with a volume V′ of a product of B′ Brix and D′ density?

$$X=\frac{V\ D\ B\ P+V'\ D'\ B'\ P'}{V\ D\ B+V'\ D'\ B'}$$

Example.—If 2,270 gallons of molasses of 94 Brix and 83 purity are mixed with 4,000 gallons of juice of 12.5 Brix and 93 purity, what is the purity of the mixture?

$$\frac{(2{,}270\times 1.514\times 94\times 83)+(4{,}000\times 1.051\times 12.5\times 93)}{(2{,}270\times 1.514\times 94)+(4{,}000\times 1.051\times 12.5)}=84.4$$

If it happens that the Brix, and consequently the densities, of the two substances are the same, the formula becomes considerably simpler:

$$X=\frac{V\ P+V'\ P'}{V+V'}$$

Problem 20.—Given a mixture of various products of volumes V, V′, V″, etc., having, respectively, Brix B, B′, B″, etc., corresponding to densities D, D′, D″, etc., and purities P, P′, P″, etc., what is the purity of the mixture?

$$\frac{V\ D\ B\ P+V'\ D'\ B'\ P'+V''\ D''\ B''\ P''+\text{etc.}}{V\ D\ B+V'\ D'\ B'+V''\ D''\ B'',+\text{etc.}}$$

Problem 21.—Given a volume V of a product of B Brix, D density, and P purity, what volume of a product of B″ Brix, D″ density, and P″ purity must be added in order to obtain a mixture of P′ purity?

$$X=\frac{V\ D\ B\ (P'-P)}{D''\ B''\ (P''-P')}$$

Example.—How much juice of 12.5 Brix and 93 purity must be added to 2,000 gallons of massecuite of 94 Brix and 83 purity to bring the purity up to 84?

$$\frac{2{,}000\times 1.514\times 94\ (84-83)}{1.051\times 12.5\ (93-84)}$$

Problem 22.—Given a product of B Brix and P purity, how much sucrose must be added to 100 parts by weight to raise the purity to P′?

$$X=\frac{B\ (P'-P)}{100-P'}$$

Example.—How much sucrose must be added to 100 pounds of molasses of 82 Brix and 68 purity to raise the purity to 85?

$$\frac{82\ (85-68)}{100-85}=92.93 \text{ pounds}$$

Problem 23.—Given a product of B Brix and P purity, how much raw sugar of a given polarization and moisture must be added to 100 parts by weight to raise the purity to P′?

$$X=\frac{100\ B\ (P'-P)}{B''\ (P''-P')} \quad \text{where } B''=100-\text{moisture, and}$$

$$P''=\frac{\text{Polarization of sugar}\times 100}{100-\text{moisture}}$$

Example.—How much sugar polarizing 89.1 and containing 1 per cent moisture must be added to 100 pounds of molasses of 82 Brix and 68 purity to raise the purity to 85?

$$B''=100-1=99;\ P''=\frac{100\times 89.1}{100-1}=90$$

$$\frac{100\times 82\ (85-68)}{99.(90-85)}=281.62 \text{ pounds}$$

Problem 24.—Given a volume V of a product of B Brix D density, and P purity, what weight of sucrose must be added to raise the purity to P′?

V being given in cubic centimeters, the result in grams will be:

$$X=\frac{V\ D\ B\ (P'-P)}{100\ (100-P')}$$

Example.—How much sucrose must be added to 200 cc. of a molasses having a Brix of 82 and purity of 68 to raise the purity to 85?

$$\frac{200\times 1.429\times 82\ (85-68)}{100\ (100-85)}=265.6 \text{ grams}$$

V being given in gallons, the result in pounds will be

$$X=\frac{8.33\times V\ D\ B\ (P'-P)}{100\ (100-P')}$$

Example.—How many pounds of sucrose must be added to 200 gallons of molasses having 82 Brix and 68 purity, to raise the purity to 85.

$$\frac{8.33\times 200\times 1.429\times 82\ (85-68)}{100\ (100-85)}=2{,}204.3 \text{ pounds}$$

Problem 25.—Given as volume V of a product of B Brix, D density, and P purity, what weight of raw sugar of a given polarization and moisture must be added to raise the purity to P′?

B″ and P″ are obtained as in Problem 23.

V being given in cubic centimeters, the result will be

$$X = \frac{V\,D\,B\,(P' - P)}{B''\,(P'' - P')}$$

Example.—How much sugar polarizing 89.1 and containing 1 per cent moisture must be added to 200 cubic centimeters molasses of 82 Brix and 68 purity to raise the purity to 85?

$$\frac{200 \times 1.429 \times 82\ (85 - 68)}{99\ (90 - 85)} = 804.9 \text{ grams}$$

V being given in gallons, the result in pounds will be

$$X = \frac{8.33 \times V\,D\,B\,(P')}{B''\,(P'' - P')}$$

Example.—How much sugar polarizing 89.1 and containing 1 per cent moisture must be added to 200 gallons of a molasses of 82 Brix and 68 purity to raise the purity to 85?

$$\frac{8.33 \times 200 \times 1.429 \times 82\ (85 - 68)}{90\ (90 - 85)} = 6{,}704.8 \text{ pounds}$$

C—DILUTION PROBLEMS

PROBLEM 26.—Given a volume V of a product of B Brix and D density, what volume of water must be added to reduce the Brix to B′? (See problem 1).

$$X = \frac{V\,D\,(B - B')}{B'}$$

Example.—How many gallons of water must be added to 200 gallons of a molasses of 80 Brix to lower it to 60 Brix?

$$\frac{200 \times 1.416\ (80 - 60)}{60} = 94.4 \text{ gallons}$$

PROBLEM 27.—Given a volume V of a product of B Brix and D density, what volume of a product of B″ Brix and D″ density must be added to reduce the Brix of the first product to B′?

$$X = \frac{V\,D\,(B - B')}{D''\,(B' - B'')}$$

Example.—Having 200 gallons of massecuite of 95 Brix and 1.521 density, how many gallons of dilute molasses of 50 Brix and 1.233 density must be added to obtain a mixture of 92 Brix?

$$\frac{200 \times 1.521\ (95 - 92)}{1.233\ (92 - 50)} = 17.6 \text{ gallons}$$

As may be seen by reference to problem 10, if only proportions have to be taken into consideration, many of these problems can be very easily solved. Thus:—Having a massecuite of 85 Brix which it is desired to dilute to 25 Brix for purposes of analysis, take 25 grams of the massecuite and make up to 85 grams with water.

Having a solution of soda of 30 per cent by volume which it is desired to dilute to 10 per cent by volume, take 10 cc. of the 30 per cent soda and dilute to 30 cc. with water.

With density figures, use the figures to the right of the decimal point. Having a liquid of 1.315 density, to dilute it to 1.150 density, take 150 cc. and dilute with water to 315 cc.

As remarked before, no allowance is made in volume calculations for contraction of volumes of liquids in dilution problems.

SECTION IV

EVAPORATION

PROBLEM 28.—Knowing that there are evaporated a volume of V gallons of juice of B Brix and D density, what is the volume of syrup obtained, if the syrup has a Brix B′ and density D′?

$$\text{From Brix: } X = \frac{V\,D\,B}{B'\,D'}$$

Example.—23,470 gallons of juice of 13.3 Brix on evaporation give a syrup of 63.5 Brix, how many gallons of syrup are obtained?

$$\frac{23{,}470 \times 13.3 \times 1.054}{63.5 \times 1.311} = 3{,}952 \text{ gallons}$$

$$\text{From densities: } X = \frac{V\,(D-1)}{D'-1}$$

$$\frac{23.470\,(1.054-1)}{1.311-1} = 4{,}075 \text{ gallons}$$

REMARK.—There will usually be a greater or less difference in the results obtained by these two formulas, according to the table used in comparing Brix and density. The former formula is to be preferred.

PROBLEM 29.—Knowing the Brix B, density D, and volume V of juice evaporated and Brix of syrup, what volume of water is evaporated?

$$\text{From problem 1, } X = \frac{V\,C\,(B'-B)}{B'}$$

Example.—Using the figures of the example in problem 28, there will be evaporated

$$\frac{23{,}470 \times 1.054\,(63.5-13.3)}{63.5} = 19{,}556 \text{ gallons}$$

$$\text{From problem 28, } X = \frac{V\,(B'\,D' - B\,D)}{B'\,D'} \text{ and}$$

$$\frac{23{,}470\,[(63.5 \times 1.311) - (13.3 \times 1.054)]}{63.5 \times 1.311} = 19{,}517 \text{ gallons}$$

$$\text{From densities, } X = \frac{V\,(D'-D)}{D'-1}$$

$$\frac{23{,}470\,(1.311-1.054)}{1.311-1} = 19{,}395 \text{ gallons}$$

SECTION V

MASSECUITES

REMARK.—Some of these problems have already been presented in previous chapters, but are repeated for the sake of facilitating application to particular conditions. As before, for exact results, it is necessary to take true total solids and true purities.

PROBLEM 30.—Knowing the Brix B of syrup and Brix B′ of the resulting massecuite, how much water is evaporated per 100 parts by weight of syrup?

$$X=\frac{100\ (B'-B)}{B'}$$

Example.—From a syrup of 61 Brix, a massecuite of 94 Brix is obtained. How much was evaporated from 100 pounds of syrup.

$$\frac{100\ (94-61)}{94}=35.1 \text{ pounds}$$

PROBLEM 31.—Knowing the Brix B and density D of syrup, and Brix D′, density D′ of the resulting massecuite, what volume of water is evaporated from a given volume V of syrup?

$$X=\frac{V\ (D'\,B'-D\,B)}{D'\ B'}$$

$$\text{or approximately, } X=\frac{V\,D\ (B'-B)}{B'}$$

Example.—From 500 gallons of syrup of 58.5 Brix, 1.281 density, a massecuite of 93 Brix and 1.056 density is obtained. What volume of water is evaporated?

$$\frac{500\ (1.506\times 93-1.281\times 58.5)}{1.506\times 93}=232.5 \text{ gallons,}$$

$$\text{or approximately, } \frac{500\times 1.281\ (93-58.5)}{93}=237.6 \text{ gallons}$$

PROBLEM 32.—Knowing the volume V′, Brix B′, and density D′ of a massecuite, and the Brix B and density D of the syrup, how much water was evaporated?

$$X=\frac{V'\ (D'\,B'-D\,B)}{D\,B}$$

$$\text{or approximately, } X=\frac{V'\,D'\ (B'-B)}{B}$$

Example.—267.5 gallons of massecuite of 93 Brix, 1,506 density, are obtained from a syrup of 58.5 Brix and 1.281 density. How much water was evaporated?

$$\frac{267.5\ (1.506\times 93-1.281\times 58.5)}{1.281\times 58.5}=232.4 \text{ gallons or}$$

$$\frac{267.5\times 1.506\ (93-58.5)}{58.5}=237.6 \text{ gallons}$$

PROBLEM 33.—Given a syrup of B Brix and a resulting massecuite of B′ Brix, how much of the latter is there obtained per 100 parts by weight of the former?

$$X=\frac{100\ B}{B'}$$

Example.—How much massecuite of 94 Brix is obtained from 100 pounds of syrup of 61 Brix

$$\frac{100\times 61}{94}=64.9 \text{ pounds}$$

PROBLEM 34.—Given a volume V of a syrup of B Brix and D density, what volume of a massecuite of B′ Brix and D′ density is obtained?

$$X=\frac{B\ D\ V}{B'\ D'}$$

Example.—From 500 gallons of syrup of 58.5 Brix and 1.281 density, a massecuite of 93 Brix and 1.506 density is obtained. How many gallons of massecuite result?

$$\frac{58.5\times 1.281\times 500}{93\times 1.506}=267.5 \text{ gallons}$$

PROBLEM 35.—Given a syrup of B Brix, D density, and P purity, and a molasses of B″ Brix, D″ density, and P″ purity, from which it is desired to produce of a mixture of a volume V′ and purity P′. What volumes of syrup and molasses must be taken?

The volume of syrup will be:

$$X=\frac{V'\ D''\ B''\ (P'-P'')}{D\ B\ (P-P')+D''\ B''\ (P'-P'')}$$

The volume of molasses will be equal to V′ − X.

Example.—It is desired to secure 2,072 gallons of a mixture of syrup and molasses of a purity of 80. The syrup is 60 Brix, 1.29 density and 90 purity; the molasses is 80 Brix, 1.416 density and 50 purity. How many gallons of each must be used?

$$\frac{2{,}072\times 1.416\times 80\ (80-50)}{1.29\times 60\ (90-80)+1.416\times 80\ (80-50)}=1{,}687.6 \text{ gallons}$$

of syrup, and 2,072 − 1,687.6 = 384.4 gallons of molasses.

PROBLEM 36.—Given a syrup of B Brix, D density, and P purity, and a molasses of B″ Brix, D″ density, and P″ purity. From these materials it is desired to boil a strike which at completion shall have a volume of V′, Brix B′, density D′, and purity P′. How much of each material must be used?

$$\text{Syrup, volume}=\frac{V'\ D'\ B'\ (P-P'')}{D\ B\ (P-P'')}$$

$$\text{Molasses, volume}=\frac{V'\ D'\ B'\ (P-P')}{D''\ B''\ (P-P'')}$$

Example.—Given a syrup and molasses of the same composition as in problem 35, how many gallons of each must be used in order to obtain a strike which at completion should measure 277 cubic feet (2,072 gallons), and have a Brix of 94, density 1.514, and purity of 80.

$$\text{Syrup} = \frac{2{,}072 \times 1.514 \times 94\ (80.50)}{1.29 \times 60\ (90-50)} = 2{,}857 \text{ gallons}$$

$$\text{Molasses} = \frac{2{,}072 \times 1.514 \times 94\ (90-80)}{1.416 \times 80\ (90-50)} = 650.8 \text{ gallons}$$

PROBLEM 37.—Given a volume V, Brix B, and density D of a massecuite, the molasses of which has a Brix B′ and density D′, what is the volume of the molasses?

$$X = \frac{V\ D\ (100-B)}{D'\ (100-B')}$$

Example.—300 gallons of massecuite of 94 Brix and 1.514 density give a molasses of 89 Brix and 1.478 density. What is the volume of the molasses?

$$\frac{300 \times 1.514\ (100-94)}{1.478\ (100-89)} = 167.6 \text{ gallons}$$

PROBLEM 38.—Given a volume of V. Brix B, and density D of a massecuite, the molasses of which has a Brix B′ and density D′, how much water must be added to reduce the Brix of the molasses to B″?

The volume of the molasses V′ is found from Problem 37, and then from Problem 26.

$$X = \frac{V'\ D'\ (B'-B'')}{B''}$$

Example.—Given 300 gallons of massecuite of 94 Brix and 1.514 density, the molasses of which has 89 Brix and 1.478 density, what quantity of water must be added to lower the Brix of the molasses to 84?

The volume of molasses is 167.6 gallons.

$$\frac{167.6 \times 1.478\ (89-85)}{85} = 11.66 \text{ gallons}$$

PROBLEM 39.—Given a volume V, Brix B, and density D of a massecuite, the molasses of which has a Brix B′, density D′, and purity P′, what quantity of molasses having a Brix B^1, density D^1, and P^1, must be added to lower the Brix of the molasses in the massecuite to B″, and what will be the resulting purity of the molasses.

The volume V′ of the molasses in the massecuite before dilution is obtained from Problem 37.

Knowing the quantity of molasses in the given volume of massecuite, the necessary amount of molasses to be added is:

$$V_1 = \frac{V' D' (B' - B'')}{D_1 (B'' - B_1)}$$

This being determined, the purity of the resulting molasses is

$$P'' = \frac{V' D' P' + V_1 D_1 P_1}{V' D' + V_1 D_1}$$

Example.—300 gallons of massecuite of 94 Brix and 1.514 density, the molasses of which has 89 Brix; 1.478 density and 81 purity being given, how much molasses of 50 Brix, 1.233 density and 75 purity must be added to reduce the Brix of the molasses to 85, and what will be the resulting purity.

The quantity of molasses originally present is—

$$\frac{300 \times 1.514\ (100 - 94)}{1.478\ (100 - 89)} = 167.6 \text{ gallons}$$

The necessary amount of molasses to add will be:

$$\frac{167.6 \times 1.478\ (89 - 85)}{(85 - 50)\ 1.233} = 23 \text{ gallons}$$

The purity of the resulting molasses will be:

$$\frac{(167.6 \times 1.478 \times 81) + (23 \times 1.233 \times 75)}{(167.6 \times 1.478) + (23 \times 1.233)}$$

PROBLEM 40.—Knowing the Brix, sucrose, ash, and purity of a massecuite and resulting molasses, what is the amount of sucrose which can be obtained from 100 parts by weight?

(*a*) From Brix, $X = \frac{100\ (B - B')}{100 - B'}$

(*b*) From sucrose, $X = \frac{100\ (S - S')}{100 - S'}$

(*c*) From ash, $X = \frac{100\ (A' - A)}{A'}$

(*d*) From purity and Brix of massecuite, $X = \frac{B\ (P - P')}{100 - P'}$

Example.—100 pounds of massecuite of the following composition, Brix 94, sucrose 84.6, purity 90, ash 3.5, give a molasses of Brix 89, sucrose 71.73, purity 80.6, ash 6.41. What quantity of sucrose can be obtained?

(*a*) $\frac{100\ (94 - 89)}{100 - 89} = 45.4$ pounds

(*b*) $\frac{100\ (84.6 - 71.73)}{100 - 71.73} = 45.4$ pounds

(*c*) $\frac{100\ (6.41 - 3.50)}{6.41} = 45.4$ pounds

(*d*) $\frac{94\ (90 - 80.6)}{100 - 80.6} = 45.5$ pounds

PROBLEM 41.—Given a volume V in gallons of massecuite of Brix B, density D, and purity P, the molasses of which has a purity P′, how many pounds of pure sugar can be obtained?

$$X=\frac{8.33\ V\ D\ B\ (P-P')}{100\ (100-P')}$$

Example.—From 300 gallons massecuite of 94 Brix, 1.514 density, and 90 purity, whose molasses has a purity of 75, how much sucrose can be recovered?

$$\frac{8.33\times300\times1.514\times94\ (90-75)}{100\ (100-75)}=2{,}133.9\text{ pounds}$$

PROBLEM 42.—What weight of sugar of a given polarization and moisture content can be obtained from 100 parts by weight of a massecuite having Brix B and purity P, the molasses of which has a purity P′?

The Brix B″ and purity P″ of the sugar being obtained as in Problem 23.

$$X=\frac{100\ B\ (P-P')}{B''\ (P''-P')}$$

Example.—From 100 pounds of a massecuite having a Brix of 94 and purity of 90, the molasses of which has a purity of 75, how much sugar containing 1 per cent moisture and polarizing 97.51 may be obtained.

$$B''=100-1=99.\quad P''=\frac{97.51\times100}{99}=98.5$$

$$X=\frac{100\times94\ (90-75)}{99\ (98.5-75)}=60.6\text{ pounds}$$

PROBLEM 43.—What weight of sugar of a given polarization and moisture content can be obtained from a volume in gallons V of massecuite of Brix B, density D, and purity P, the molasses of which has a purity P′?

The Brix and purity being obtained as in Problem 42,

$$X=\frac{8.33\ V\ D\ B\ (P-P)}{B''\ (P''-P')}$$

Example.—How much sugar of 1 per cent moisture and 97.51 polarization can be obtained from 300 gallons of a massecuite having a Brix of 94, density of 1.514, and purity 90, the molasses of which has a purity of 75?

$$\frac{8.33\times300\times1.514\times94\ (90-75)}{99\ (98.5-75)}=2293\text{ pounds}$$

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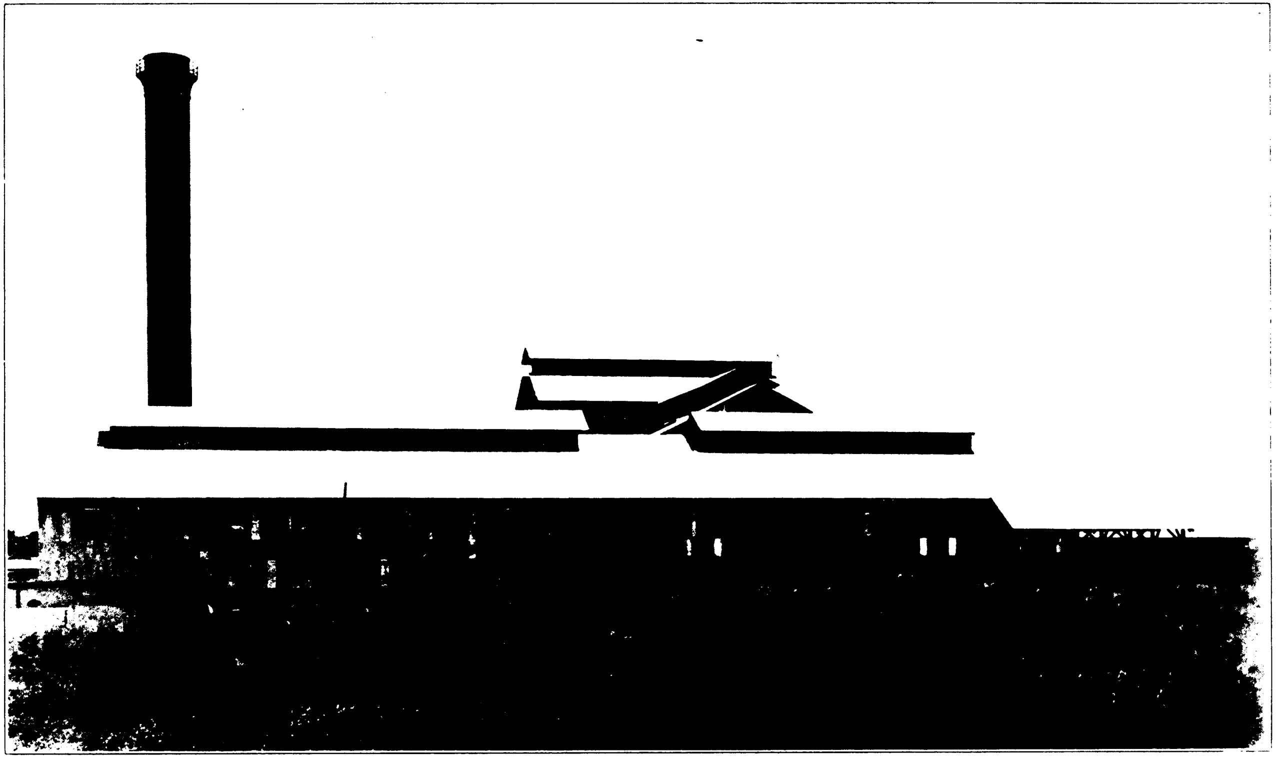

PLATE XIV. Modern sugar factory, which is highly efficient in operation and produces a good grade of marketable sugar

PLATE XIII. Antiquated muscovado factory. This type of factory is being rapidly replaced by the modern centrifugal factory

SUPERIORITY OF MODERN CENTRAL

The question is often asked: What is the relative advantage of the modern sugar central over the small open-kettle factory.

The modern sugar central of today extracts from 92 to 98 per cent of the sucrose contained in the cane. The work throughout the factory is conducted in the most efficient manner, under strictly scientific control, and a high grade of commercial sugar is manufactured which meets the requirements of present day market demands. Due to the employment of labor saving devices, the manufacturing operations are effected with a minimum amount of labor, which in itself assists in solving a very important problem on sugar plantations.

The small open-kettle factory is wasteful in sugar, labor, and time. It extracts but a small percentage of the juice from the cane, and this results in bagasse which is unfit for direct consumption in the furnaces. Labor, then, is required to scatter the bagasse over the ground in the sun and collect it again and transfer it to the furnaces when it is dry. Due to the crude methods invariably followed throughout the factory, there is a great waste of sugar during the process of manufacture. This antiquated system requires, too, the employment of many workmen in the numerous small factories at a time when they are badly needed to conduct the field work.

Practically all of the impurities originally extracted from the cane are left in the so-called clarified juice, due to the inefficient methods of clarification. These impurities are later found in the finished sugar, which is the principal reason for its dark color and low quality.

It is the purities of the various juices which in the main account for the variance in the results of tests made to compare the work of modern central factories and open-kettle mills. With a reduction in the purity of cane juices there is an increase in the percentage of molasses removed at the modern factory in order to bring the finished sugar up to the customary 96° polarization. In the case of the open kettle factory all of these impurities are included with the sugar, and as before mentioned, this is largely responsible for its resulting low quality.

Herewith is a report showing the comparative efficiency between a modern sugar central and an open-kettle mill in one of the principal sugar districts of the Philippines:

	Small factory[a]	Modern sugar central[b]
	Kilos	*Kilos*
Cane ground	73,171.00	70,671.00
Juice	50,220.00	59,000.00
Bagasse	22,951.00	11,671.00
Sugar produced	9,127.00	9,095.00
Sugar per 100 cane	12.47	12.87
	Per cent	*Per cent*
Mill juice Brix	20.90	20.30
Mill juice sucrose	17.83	17.83
Mill juice purity	85.60	85.60
Mixed juice Brix		14.90
Mixed juice sucrose		12.50
Mixed juice purity		83.80
Syrup Brix	38.90	
Syrup sucrose	32.80	
Syrup purity	85.30	
Fiber per cent cane	10.00	10.00
Fiber per cent bagasse	31.80	46.00
Sucrose per cent bagasse	9.80	4.70
Dilution per cent normal juice		32.20
Sucrose per cent cane	14.99	14.99
Sucrose bagasse per cent cane	3.07	1.02
Extraction sucrose per cent cane	11.92	13.27
Extraction sucrose per cent sucrose in cane	74.20	93.20
Polarization of sugar produced	80.00	96.5
Losses per cent sucrose	33.43	17.15

SUMMARY

	Kilos.	*Kilos.*
Sucrose recovered	7,301.00	8,776.5
Sucrose lost in bagasse	2,250.00	721.0
Sucrose lost in molasses and undetermined		1,095.5
Sucrose lost in undetermined (inversion etc.)	1,417.00	
Total	10,968.00	10,593.00

	Cane	Sucrose in cane	Cane	Sucrose in cane
	P'cent	*P'cent*	*P'cent*	*P'cent*
Sucrose recovered	9.97	66.57	12.42	82.85
Sucrose lost in bagasse	3.07	20.51	1.02	6.80
Sucrose lost in molasses and undetermined			1.55	10.35
Sucrose lost in undetermined (inversion etc.)	1.95	12.92		
Total	14.99	100	14.99	100

[a] Contained three rollers 22 by 40 inches scum tanks, mud presses and open kettles.

[b] Contained nine rollers 34 by 78 inches crusher, modern clarifiers, vacuum pan, and centrifugals.

CONCLUSIONS

The Modern Sugar Central produced 24.6 per cent more 96.5° sugar than the open-kettle mill. Assuming the losses in process of actually converting 80° sugar into 96.5° sugar to be 10 per cent (which is a conservative estimate) of the sucrose content of the 80° sugar, there would be a saving of 38.4 per cent of 96.5° sugar in favor of the modern mill.

Comparison of value of the two sugars taken from actual figures

Open-kettle factory	Cost to planter	Modern sugar central mill
	Per picul	
Crushing	0.20	
Boiling	0.125	
Handling bagasse	0.11	
Clarifying juice	0.01	
Drying and bagging	0.05	
Carrying to landing	0.005	
Containers	0.15	
Mill supplies	0.06	Nothing
Superintendence	0.075	
Loading vessels	0.01	
Discharging and storing, Iloilo	0.03	
Extra containers	0.053	
Weighing	0.02	
Insurance	0.014	
Freight	0.25	
Total	1.162	

Taking 100 piculs of the same cane

Open-kettle mill 12.47 piculs 80° sugar:	
Selling price in Iloilo at ₱4.60 per picul	₱57.36
Deducting cost of manufacturing and freight only	14.73
Net selling price	42.63
Gain by central	8.12
	₱50.75

Modern sugar central 12.87 piculs 96.5 sugar:	
Selling price United States at 8.64 per picul	₱111.19
Deducting freight to New York at ₱0.753 per picul	9.69
Deducting 50% of ₱101.50 that central receives 50.75	60.44
Net selling price	₱50.75

It can thus be seen at a glance that there is a net gain of ₱8.12 for the planter who sends his sugar to a modern sugar central.[1]

The planter who mills his cane in the central factory is not required to spend money for the repair and upkeep of a small mill.

The sugar which he receives as his share from the cane is of a type which meets present day demands and brings the highest market price, in addition such sugar may be stored for a long period of time without appreciable deterioration, as a result of the low moisture content and the absence of impurities.

Due to the economy in labor effected by the modern central, a large supply of laborers is liberated for work on the plantations. In consequence the cane could be cut at the proper time in order to obtain the maximum sucrose it is capable of yielding. Likewise the planter is able to prepare and plant his land early while there is an abundance of moisture in the soil. Thus the cane can root down to a permanent supply of moisture by the time dry weather sets in and instead of the growth being checked or the cane perhaps actually dying during the prolonged drouth, the constant sunshine causes it to make a steady growth.

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[1] From a report submitted by the planters' committee.

So, instead of the planter harvesting a small crop of cane and having a poor stand for his ratoon crop, with the plentiful supply of labor he is able to harvest large crops and in many cases ratoon his cane for several years, thus eliminating the extra expense of land preparation and planting each year. Last but not by any means least, instead of the planter remaining a debtor to rich sugar merchants and others, each year borrowing money to carry him over the planting and harvest season and paying back perhaps with usury as soon as he is able to throw his low grade sugar on the market, in a few years, under the modern system, he is able to handle an account on the credit side of the ledger and if he so desires he can loan money to his less fortunate planters who do not have the opportunities of milling their cane in a modern central factory.

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